# Ford General Body Builder Layout Book

## Table of Contents

Introduction ..... 4
Reference Information ..... 4
Definitions ..... 5
Terminology ..... 5
VIN Coding Information ..... 7
New Vehicle and Long Term Storage Guidelines ..... 8
Design Recommendations ..... 9
Second Unit Body Structures and Mounting ..... 9
Body Components ..... 9
Attaching Accessories to Aluminum Panels and Structure ..... 9
Attaching Accessories to Magnesium Structure ..... 10
Headlight Alignment ..... 10
Heat Management ..... 11
Fuel System ..... 12
Fuel Tanks ..... 12
Fuel Tank Retention Systems ..... 12
Fuel Fill System ..... 12
Fuel Lines, Hoses and Pumps ..... 13
Fuel System Access for Auxiliary Fuel Powered Equipment ..... 14
Electrical System ..... 15
Transport Mode ..... 15
Module Configuration / Calibration ..... 15
General Practices ..... 15
Accessing Power ..... 16
Key Off Loads ..... 16
Battery Relocation ..... 16
Auxiliary Batteries vs. Multiple Batteries ..... 17
Fusing and Circuit Protection ..... 17
Electrical Wiring - General ..... 17
Electrical Wiring - Wire Gage ..... 17

Electrical Wiring - Routing & Retention ..... 17
Electrical Wiring - Splice / Repair ..... 18
Lighting ..... 18
Upfitter Interface Module (UIM) ..... 20
Cooling System ..... 24
Climate Control System ..... 24
Exhaust System ..... 25
Wheels and Tires ..... 26
Tire Pressure Monitoring System (TPMS) ..... 26
Brake System ..... 26
Suspension and Steering System ..... 28
Engine ..... 28
Transmission ..... 29
Driveline ..... 29
Driveline Balance, Runout and Sizing ..... 29
Driveline Angles ..... 30
Frame ..... 32
Wheelbase Modifications ..... 32
Aft of Axle Frame Extension ..... 35
Ground Clearance ..... 36
Occupant Protection Systems ..... 37
Seat Systems ..... 37
Lap and Shoulder Belt Systems ..... 37
Occupant Protection Zone and Overhead Console ..... 38
Air Bag Supplemental Restraints System (SRS) ..... 38
Center of Gravity Location ..... 39
Definitions ..... 39
Determining Center of Gravity Location ..... 40
Assessing Center of Gravity Location ..... 41
Change Control ..... 43

## Introduction

The information described herein is believed to be correct at the time of publication, but accuracy cannot be guaranteed. Ford reserves the right to discontinue models or change specifications or designs at any time without notice and without incurring any obligation.

Representations regarding the compliance of any Ford-manufactured incomplete vehicle to any rule, regulation or standard issued pursuant to the National Traffic and Motor Vehicle Safety Act or the Canadian Motor Vehicle Safety Act are set forth only in the Incomplete Vehicle Manual (IVM) which accompanies each incomplete vehicle.

Regulations such as those issued by the Federal Highway Administration (FHA) or issued pursuant to the Occupational Safety and Health Act (OSHA), and/or state, provincial, and local laws and regulations may require installation of additional equipment for the particular use intended for the vehicle. It is the responsibility of the subsequent stage manufacturer or completed vehicle alterer and the vehicle purchaser to ascertain how the vehicle will ultimately be used, if FHA, OSHA or state provincial or local regulations apply and how the vehicle, as completed, will comply with those requirements. Nothing contained herein is to be construed as a representation that such equipment required for the particular use intended has been installed on the completed or incomplete vehicle.

## Reference Information

### Ford Body Builder Advisory Service Publications

In addition to this General Body Builder Layout Book (BBLB), there are several other Ford BBLB documents that contain general best practices or information on specific subjects that span multiple vehicle lines. These include:

- Snow Plow BBLB
- Pickup Box Removal BBLB

In addition to the BBLBs listed above, each Ford Commercial Truck vehicle line has a program-specific Body Builders Layout Book that aims to provide detailed information which may be of interest to a subsequent-stage manufacturer or alterer.

The Ford Transit and Transit Connect also have a Body and Equipment Mounting Manual (BEMM), which is a comprehensive resource dedicated to body and equipment mounting information.

Yet another source of program-specific information is the “Vehicle Specification” documents available on the Ford BBAS website. Information typically found in these documents are: vehicle curb and accessory weights, vehicle dimensions, component descriptions, capacities, GAWRs, alternator output, powertrain output and gear ratios.

For reference, Incomplete Vehicle Manuals (IVM) for applicable Ford commercial vehicles are also provided on the Ford BBAS website.

These publications are updated every model year and can be accessed via the web at https://fordbbas.com under “Publications”. For BBLB and BEMM documents, expand the “Body Builder Layout Book” Section to view all available documents. For Vehicle Specifications, expand the “Vehicle Specifications” section. For IVMs, expand the “Incomplete Vehicle Manuals” section. The website search function can be used to filter for specific content or vehicle line.

### Ford Body Builder Advisory Service Bulletins

Occasionally, the Ford BBAS team will create an SVE “Bulletin” to address a specific issue or distribute important information in a timely manner. These documents can be accessed via the web at https://fordbbas.com under “Bulletins”. The website search function can be used to filter for specific content or vehicle line.

If applicable, information from each SVE bulletin will be incorporated into the appropriate BBLB document the following model year. In some cases, SVE bulletins will continue to be referenced in this document.

### Ford Body Builder Advisory Service Contact

The Ford Truck Body Builder Advisory Service may be consulted if questions regarding the completion of Ford commercial vehicles are not adequately addressed in the documentation described above. For assistance call (877) 840-4338 or e-mail via the web at https://fordbbas.com under “Contact Us” and select “General Questions”.

For Ford vehicle CAD requests, please visit https://fordbbas.com, select “Contact Us” and then “CAD Request”.

For both Questions and CAD Requests, please be as specific as possible with the request details to assure the most accurate and timely response.

### Ford Service Publications

Ford Service Technical Resources (including wiring diagrams, repair manuals and diagnostic tool support) are available by subscription via the Motorcraft website: www.motorcraftservice.com

The following publications are examples of digital and printed manuals which are available from Helm Incorporated; call 1-800-782-4356 or contact Helm, Inc. at their website www.helminc.com:

- Ford Shop Manuals
- Ford Towing Manuals
- Ford Wiring Diagrams

## Definitions

### Terminology

The following definitions are from Title 49, Code of Federal Regulations (49CFR), Parts 567.3, 568.3 and 571.3 where noted. Canadian definitions are from Canada Motor Vehicle Safety Regulations (CMVSR), Section 2(1), and are in italics. Ford Motor Company definitions are for the purpose of this publication, other Body Builders Layout Books and Ford Incomplete Vehicle Manuals. Some terms are followed by an abbreviation that may be used throughout this publication.

**Alterer** — a person who alters by addition, substitution, or removal of components (other than readily attachable components) a certified vehicle before the first purchase of the vehicle other than for resale. (49CFR567.3)

**Ambulance** — a vehicle for emergency medical care which provides: a driver's compartment; a patient compartment to accommodate an Emergency Medical Technician (EMT), Paramedic, and two litter patients (one patient on the primary cot and secondary patient on a folding litter located on the squad bench) so positioned that the primary patient can be given intensive life-support during transit; equipment and supplies for emergency care at the scene as well as during transport; two-way radio communication; and, when necessary, equipment for light rescue/extrication procedures. The Ambulance shall be designed and constructed to afford safety, comfort, and avoid aggravation of the patient's injury or illness. (From Federal Specification KKK-A-1822-F). Ford Motor Company also includes within its definition of ambulance any vehicle that is used for transporting life support equipment, for rescue operations, or for nonemergency patient transfer if the engine of the vehicle is equipped with a "throttle kicker" device, which enables an operator to increase engine speed over normal idle speed when the vehicle is not moving. (Ford Motor Company)

**B-Pillar** — the vehicle body structure located directly rearward of each front door. This structure will include the outer panel, all inner panels or reinforcements which support the door opening, the door latching system and/or the roof structure. (Ford Motor Company)

**Basic (Stripped) Chassis** — an incomplete vehicle, without occupant compartment, that requires the addition of an occupant compartment and cargo carrying, work performing, or load-bearing components to perform its intended function. (Ford Motor Company)

**Bus** — a motor vehicle with motive power, except a trailer, designed for carrying more than 10 persons. (49CFR571.3)

***Bus (Canada)*** *— a vehicle having a designated seating capacity of more than 10, but does not include a trailer or a vehicle imported temporarily for special purposes. (autobus)*

**Chassis Cab** — an incomplete vehicle, with completed occupant compartment, that requires only the addition of cargo-carrying, work-performing or load-bearing components to perform its intended functions. (49CFR567.3)

**Completed Vehicle** — a vehicle that requires no further manufacturing operations to perform its intended function. (49CFR567.3)

**Critical Control Item** — a component or procedure which may affect compliance with a Federal regulation, or which could directly affect the safe operation of the vehicle. The identifying symbol is an inverted delta (∇). (Ford Motor Company)

**Cutaway Chassis** — an incomplete vehicle that has the back of the cab cut out for the intended installation of a structure that permits access from the driver's area to the back of the completed vehicle. (Ford Motor Company)

***Cutaway Chassis (Canada)*** *— an incomplete vehicle that has the back of the cab cut out for the intended installation of a structure that permits access from the driver's area to the back of the completed vehicle. (châssis tronqué)*

**Designated Seating Position** — a seat location that has a seating surface width, as described in §571.10(c) of this part, of at least 330 mm (13 inches). The number of designated seating positions at a seat location is determined according to the procedure set forth in §571.10(b) of this part. However, for trucks and multipurpose passenger vehicles with a gross vehicle weight rating greater than 10,000 lb., police vehicles as defined in S7 of FMVSS 208, firefighting vehicles, ambulances, and motor homes, a seating location that is labeled in accordance with S4.4 of FMVSS 207 will not be considered a designated seating position. For the sole purpose of determining the classification of any vehicle sold or introduced into interstate commerce for purposes that include carrying students to and from school or related events, any location in such a vehicle intended for securement of an occupied wheelchair during vehicle operation is regarded as four designated seating positions. (49CFR571.3)

***Designated Seating Position (Canada)*** *— a location in a vehicle that is likely to be used as a seating position and that has a seating surface width of at least 330 mm; (place assise désignée)*

**Final-Stage Manufacturer** — a person who [company that (CMVSR)] performs such manufacturing operations on an incomplete vehicle that it becomes a completed vehicle. (49CFR567.3)

**Firefighting Vehicle** — a vehicle designed exclusively for the purpose of fighting fires. (49CFR571.3)

**Forward Control** — a vehicle configuration in which more than half of the engine length is rearward of the foremost point of the windshield base and the steering wheel hub is in the forward quarter of the vehicle length. (49CFR571.3)

**Gross Axle Weight Rating (GAWR)** — the value specified by the vehicle manufacturer as the load carrying capacity of a single axle system, as measured at the tire-ground interfaces. (49CFR571.3)

**Gross Combination Weight Rating (GCWR)** — the value specified by the manufacturer as the loaded weight of a combination vehicle. (49CFR571.3)

**Gross Vehicle Weight Rating (GVWR)** — the value specified by the manufacturer as the loaded weight of a single vehicle. (49CFR571.3)

**H-Point** — the mechanically hinged hip point of a manikin which simulated the actual pivot center of the human torso and thigh, described in SAE Recommended Practice J826, "Manikins For Use in Defining Vehicle Seating Accommodation," November 1962. (49CFR571.3)

***H-Point (Canada)*** *— the mechanically hinged hip point of a manikin that simulates the actual pivot centre of the human torso and thigh, described in SAE Standard J826APR80, Devices for Use in Defining and Measuring Vehicle Seating Accommodation. (Point H)*

**Incomplete Vehicle** — an assemblage consisting, as a minimum, of chassis (including the frame) structure, power train, steering system, suspension system, and braking system, to the state that those systems are to be part of the completed vehicle but requires further manufacturing operations to become a completed vehicle. (49CFR567.3)

***Incomplete Vehicle (Canada)*** *— a vehicle (a) other than a vehicle imported temporarily for special purposes, that is capable of being driven and that consists, at a minimum, of a chassis structure, powertrain, steering system, suspension system, and braking system in the state in which those systems are to be part of the completed vehicle, but requires further manufacturing operations to become a completed vehicle or (b) that is an incomplete trailer. (véhicule incomplet)*

**Incomplete Vehicle Manufacturer** — a person [company that (CMVSR)] who manufactures an incomplete vehicle by assembling components none of which, taken separately, constitute an incomplete vehicle. (49CFR567.3)

**Intermediate Manufacturer** — a person [company that (CMVSR)], other than the incomplete vehicle manufacturer or the final stage manufacturer, who performs manufacturing operations on an incomplete vehicle. (49CFR567.3)

**Motor Home** — a multi-purpose vehicle with motive power that is designed to provide temporary residential accommodations, as evidenced by the presence of at least four of the following facilities: cooking; refrigeration or ice box; self-contained toilet; heating and/or air conditioning [system that can function independently of the vehicle engine (CMVSR)]; a potable water supply system including a faucet and a sink; and a separate 110-125 volt electrical power supply and/or an LP gas supply. (49CFR571.3)

**Multifunction School Activity Bus (MFSAB)** — a school bus whose purposes do not include transporting students to and from home or school bus stops. (49CFR571.3)

**Multipurpose Passenger Vehicle (MPV)** — a motor vehicle with motive power, except a low-speed vehicle or trailer, designed to carry 10 persons or less which is constructed either on a truck chassis or with special features for occasional off-road operation. (49CFR571.3)

**Multipurpose Passenger Vehicle (MPV) (Canada)** — a vehicle having a designated seating capacity of 10 or less that is constructed either on a truck chassis or with special features for occasional off-road operation, but does not include an air cushion vehicle, an all-terrain vehicle, a golf cart, a low-speed vehicle, a passenger car, a truck or a vehicle imported temporarily for special purposes. (véhicule de tourisme â isages multiples*)*

**Pickup Box Delete** — a chassis cab incomplete vehicle created by ordering a Pickup Box Delete option on an otherwise completed vehicle. (Ford Motor Company)

**School Bus** — a bus that is sold, or introduced in interstate commerce, for purposes that include carrying students to and from school or related events but does not include a bus designed and sold for operation as a common carrier in urban transportation. (49CFR571.3)

***School Bus (Canada)*** *— a bus designed or equipped primarily to carry students to and from school. (autobusscolaire)*

**Seating Reference Point** — the unique design H-point, as defined in SAE J1100 (June 1984), which: a) establishes the rearmost normal design driving or riding position of each designated seating position in a vehicle; b) has X, Y, and Z coordinates established relative to the designed vehicle structure; c) simulated the position of the pivot center of the human torso and thigh; and d) is the reference point employed to position the two-dimensional drafting template described in SAE J826 (May 1987) (abbreviated by Ford Motor Company)

***Seating Reference Point (Canada)*** *— the unique Design H-point, as defined in section 2.2.11.1 of SAE Recommended Practice J1100 (June 1993), that: a) establishes the rearmost normal design driving or riding position of each designated seating position, taking into account all modes of adjustment - horizontal, vertical and tilt - in a vehicle, b) has X, Y, and Z coordinates, as defined in section2.2.3 of SAE Recommended Practice J1100 (June1993), established relative to the designed vehicle structure, c) simulates the position of the pivot centre of the human torso and thigh, and d) is the reference point employed to position the H point template with the 95th percentile leg, as described in section 3.1 of SAE Standard J826 (June 1992), or, if that drafting template cannot be positioned, the reference point when the seat is in its rearmost adjustment position(point de référence de position assise)*

**Second Unit Body (SUB)** — consists of the body structure and/or all the cargo carrying, work performing, and/or load bearing components and/or equipment installed by a subsequent stage manufacturer on an incomplete vehicle, such that the incomplete vehicle becomes a completed vehicle. (Ford Motor Company)

**Service Body** — a second unit body typically consisting of a box enclosure that extends below the frame level to a height above ground approximately level with the center of the rear axle and the rear bumper. (Ford Motor Company)

**Subsequent Stage Manufacturer** — a term which means either intermediate or final stage manufacturers or both. (Ford Motor Company)

**Trimmed Seat** — a complete functional seat assembly including the seat pedestal, seat track, seat base frame, seat back, recliner mechanism, seat padding, all attaching hardware, and the final trim material (i.e., cloth, leather, or vinyl). (Ford Motor Company)

**Truck** — a motor vehicle with motive power, except a trailer, designed primarily for the transportation of property or special purpose equipment. (49CFR571.3)

***Truck (Canada)*** *— a vehicle designed primarily for the transportation of property or special-purpose equipment, but does not include a competition vehicle, a crawler-mounted vehicle, a trailer, a work vehicle, a vehicle imported temporarily for special purposes or a vehicle designed for operation exclusively off-road. (camion)*

**Truck Tractor** — a truck designed primarily for drawing other motor vehicles and not so constructed as to carry a load other than a part of the weight of the vehicle and the load so drawn. (49CFR571.2)

***Truck Tractor (Canada)*** *— a truck designed primarily for drawing other vehicles and not constructed for carrying any load other than part of the weight of the vehicles and load drawn, and includes a vehicle designed to accept a fifth-wheel coupling but does not include a crane-equipped breakdown vehicle. (camion letracteur)*

**Under Body** — the area between the frame rails of a vehicle. If the vehicle does not have frame rails, the entire under area of the vehicle is included in the definition

**Under Hood** — the engine compartment area rearward of the front of the engine cooling radiator

**Unloaded Vehicle Weight (UVW)** — the weight of a vehicle with maximum capacity of all fluids necessary for operation of the vehicle, but without cargo, occupants, or accessories that are ordinarily removed from the vehicle when it is not in use. (49CFR571.3)

***Unloaded Vehicle Weight (UVW) (Canada)*** *— the weight of a vehicle equipped with the containers for the fluids necessary for the operation of the vehicle filled to their maximum capacity, but without cargo or occupants. (poids du véhicule sans charge)*

**Untrimmed Seat** — the structure including the seat pedestal, seat track, seat base frame, seat back, recliner mechanism, seat padding, and all attaching hardware required for a functional seat assembly without the final trim material (e.g., cloth, leather or vinyl) and trim material attaching components. (Ford Motor Company)

**Walk-In Van** — a special cargo/mail delivery vehicle that has only one designated seating position. That designated seating position must be forward facing and for use only by the driver. The vehicle usually has a thin and light sliding (or folding) side door for easy operation and a high roof clearance that a person of medium stature can enter the passenger compartment area in an up-right position. (49CFR571.214)

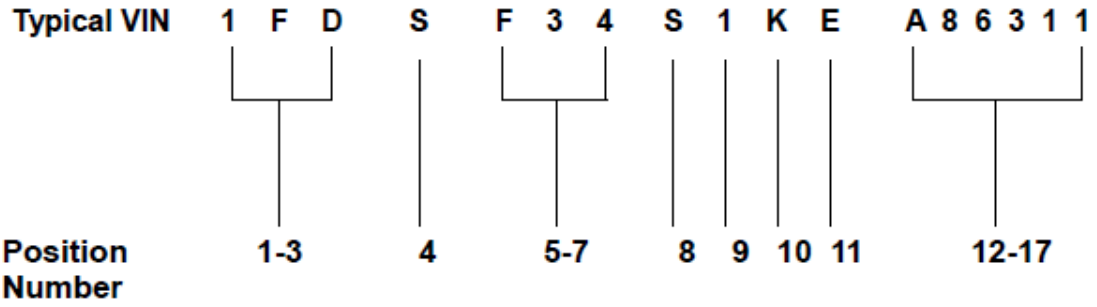
***Walk-In Van (Canada)*** *— a van type of truck in which a person having a height of 1700 mm can enter the occupant compartment in an upright position by a front door. (fourgon â accés en position debout)*

**VIN Coding Information**

Universal Vehicle Identification Numbers (VINs) have 17 “positions”. There is a number or letter in each position (see example below).

A “VIN Guide” document is accessible on the Ford Fleet web site under the “Parts and Service” tab at: www.fleet.ford.com/partsandservice/vin-guides/

A “VIN Decoder” tool is also available (login required) on the Ford Fleet web site under the “Parts and Service” tab at: www.fleet.ford.com/partsandservice/vin-decoder/




| | | |
|---|---|---|
| Positions | 1-3 | World Manufacturer Identifier |
| Position | 4 | Restraint System Type (Passenger Car Only); Brake Type, GVWR Class, and Restraint System Type (Trucks, MPVs and Buses) |
| Positions | 5-7 | Line, Series, Body Type |
| Position | 8 | Engine Type |
| Position | 9 | Check Digit |
| Position | 10 | Model Year |
| Position | 11 | Assembly Plant |
| Positions | 12-17 | Production Sequence Number |

## New Vehicle and Long Term Storage Guidelines

### General

- Wherever possible, vehicles should be stored in an enclosed, dry, well-ventilated area on firm, well drained ground which is free of long grass or weeds and protected from direct sunlight.
- For stripped chassis, ensure chassis interior and dunnage box are protected from the elements.
- For cutaways and door delete models, ensure back panel plastic sheet is intact and/or temporary door is in place when vehicles are stored outside or moved.
- Any chassis with an incomplete roof modification should not be stored outside unless appropriately protected.

### Body

- Wash the vehicle thoroughly to remove dirt, grease, oil, tar, or mud from exterior surfaces, rear wheel housing, and underside of front fender. Periodically re-wash vehicles stored in exposed locations.
- Touch up exposed raw or primed metal to provide rust protection.
- Cover chrome and stainless-steel parts with a thick coat of auto wax to prevent discoloration. Re-wax as necessary when the vehicle is washed.
- Keep all rubber parts free from oil and solvents.
- Cover the interior soft trim to prevent fading, if stored in exposed location.
- Make sure that all windows, doors, hood, and roof opening panel are completely closed.
- Set climate controls to the "open" position to provide ventilation, where possible.
- All SUB air intakes should be closed.

### Engine / Transmission

- Start the engine every 15 days and move the vehicle at least 25 feet. Run the engine until it reaches normal operating temperature. With your foot on the brake, shift the transmission through all the gears (R, N, D etc.) while engine is running.
- Check for fluid leaks under the vehicle.
- Confirm the transmission fluid dipstick (if equipped) is fully seated in the tube.
- Stripped Chassis vehicles – cover transmission vent to prevent water from entering through the vent, including steady water runoff from surrounding components.

### Fuel System

- Fill the fuel tank with high-quality fuel until the first automatic shutoff of the fuel pump nozzle.
- Every 15 days move the vehicle at least 25 feet to mix fuel anti-oxidation agents.
- A commercially available gasoline fuel stabilizer (“Sta-Bil” or equivalent) should be added to gasoline powered vehicles or a diesel fuel stabilizer (“Fire Prep 100” or equivalent) to diesel powered vehicles whenever expected or actual storage periods exceed 60 days. The manufacturer’s instructions packaged with the product should be followed. The vehicles should then be operated at an idle speed to circulate the additive throughout the fuel system. Fuel stabilizer helps prevent oxidation, which could cause damage to rubber or plastic materials in the fuel system or clog the fuel supply system.

### Cooling System

- Maintain appropriate antifreeze protection against freezing temperatures.
- Only use coolant as recommended in your vehicle owner's manual.

### Battery

- If new vehicles are to be stored for extended periods of time, vehicles should be left in “Transport Mode” if possible, as this will reduce drain on the battery. For more information see Design Recommendations – Electrical System – Transport Mode
- During extended vehicle storage, make sure the battery voltage never drops below 12.4 volts in order to maintain battery life. The use of a Battery maintenance charger is ideal as it monitors the battery voltage and charges it as necessary.
- If it is not possible to use a maintenance charger, disconnect the battery negative terminal during storage of more than 30 days to prevent the vehicle from discharging the battery. (Note that if the vehicle battery is disconnected, it will be necessary to reset vehicle memory features.) Make sure the battery is at full charge prior to storage, then measure the voltage every three to six months and charge the battery if it falls below 12.4 volts.
- Keep battery connections clean and covered with a light coat of grease.

### Brakes

- Make sure service brakes and the parking brake are fully released. Apply suitable wheel chocks to prevent vehicle from moving.

### Wheels and Tires

- Maintain recommended air pressures.
- Wheel trims (where fitted) should be removed and stored inside the vehicle.

### Miscellaneous

- Verify that all linkages, cables, clevis pins, and levers under the vehicle are covered with grease to prevent rust.

### Removing the Vehicle from Storage

- Wash the vehicle to remove any dirt or grease film build-up on window surfaces.
- Check battery voltage and charge as necessary. Reconnect cables if they had been disconnected.
- Check windshield wipers for any deterioration.
- Check under the hood for any foreign material that may have collected during storage such as mice or squirrel nests.
- Check the exhaust for any foreign material that may have collected during storage.
- Check tire pressures and set tire inflation per the Tire Label.
- Check that fluids are at appropriate levels (engine coolant, engine oil, fuel, wiper washer fluid etc.).
- Check brake pedal operation. Drive your vehicle 15 feet (4.5 m) back and forth to remove rust build-up.

## Design Recommendations

The following recommendations are intended to assist in the design of various systems and components with the aim of creating a completed vehicle that meets regulatory and customer needs. Since completed vehicles my take many forms, the following recommendations cannot cover all the possibilities.

### Second Unit Body Structures and Mounting

The structural design and materials used in the construction of second unit bodies must be sufficient to help control collapse of the body and prevent disengagement from the chassis when tested in accordance with applicable regulations. Steel or aluminum structures are recommended, wood or composite materials may require additional reinforcements to provide the necessary structural integrity. SUB structures should not extend rearward beyond (overhang) the end of the frame side members.

Please see the applicable program specific Incomplete Vehicle Manual and/or Body Builder Layout Book for requirements and recommended best practices for SUB to chassis mounting for that vehicle

SUB floor and bulkhead structures must accommodate the Ford fuel fill system and appropriate design clearances. Fuel fill neck locations and compliance representations regarding fuel systems are in the Statements of Conformity section of the Incomplete Vehicle Manual. See the section on Fuel Systems in this document for additional information that may apply to the Second Unit Body.

### Body Components

The following recommendations should be heeded regarding body components:

- Running boards or entry steps should use a mounting system that will attach only to the body. A system that combines both frame and body mounting points may cause frame induced noise, vibration, and harshness (NVH) to transfer through the mounting system into the body. This also may result in increased risk for component, body and/or frame damage and loosening of attaching fasteners.
- Use a butyl type sealer on the raw edges of modified steel body sheet metal panels to prevent corrosion.
- Temporary mounting pads may eliminate chipping and scratches when accessories are installed.
- Select material pairs that are compatible to prevent galvanic corrosion. See section of this document regarding mounting to aluminum and magnesium components.
- When adding holes to the floor of the vehicle, consideration must be given to all components below the floor. The use of drill stops is recommended to prevent accidental damage.
- Fasteners added to the floor should not point at the fuel tank (in design position or when deformed in a crash situation) or should be appropriately shielded.
- Components with sharp edges in proximity to the fuel tank should be avoided or appropriately shielded to eliminate the possibility of fuel tank penetration in crash situations.
- When a closed Second Unit Body (SUB) or rear panel is attached directly to the back of a Cutaway body, difficulty may be experienced when closing doors due to air pressure build up. It is recommended that vent(s) be installed to allow “ONE WAY” pressure release from the inside of the cab to the outside. The recommended minimum size of the venting is 36 square inches.
- Added body vents, especially powered vents, should be located away from the fuel fill, fuel system vents and exhaust outlets to avoid fuel vapors and exhaust gas entering the interior of the vehicle.

Attaching Accessories to Aluminum Panels and Structure

Vehicle modifiers should take note that when installing aftermarket equipment, corrosion can occur if dissimilar metals are in contact with aluminum body panels or structure. This type of corrosion is called “galvanic” corrosion.

Any time the factory paint is disturbed, it is recommended that the paint be repaired with a suitable coating prior to installing aftermarket equipment (i.e. splash guards, bug shields, tool boxes, etc.). When installing steel fasteners into the mounting hole, the fastener should not have contact with the aluminum sheet metal. For zinc coated steel bolts and screws, an aluminum washer should be used. For further protection, an isolation layer such as polypropylene or urethane tape can be used between the dissimilar metals

Approved Anti-Corrosion Coatings
- Motorcraft PM13-A
- NOX-Rust 7703-W
- Zinc Rich Primer

Recommended Acrylic Lacquer Touch-up Paints
- Motorcraft
- Duplicolor
- Rustoleum

Approved Fasteners
- Aluminum Clamps
- Aluminum Blind Pull-Pin Rivets
- Plastic Trim Pins
- Plastic Push Pins
- Aluminum Rivet nuts
- Zinc coated steel fasteners used with an aluminum washer

Isolator Recommendations
- Aluminum washer
- Urethane tape
- Polypropylene tape

The following figures illustrate some best practices to prevent dissimilar metals from coming in contact with aluminum.

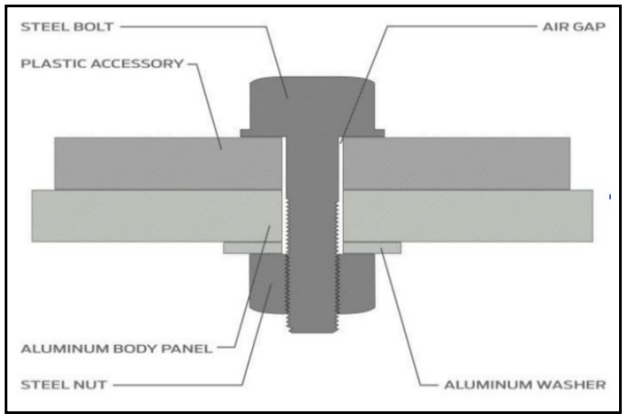



**Figure 1 – Plastic Accessory**

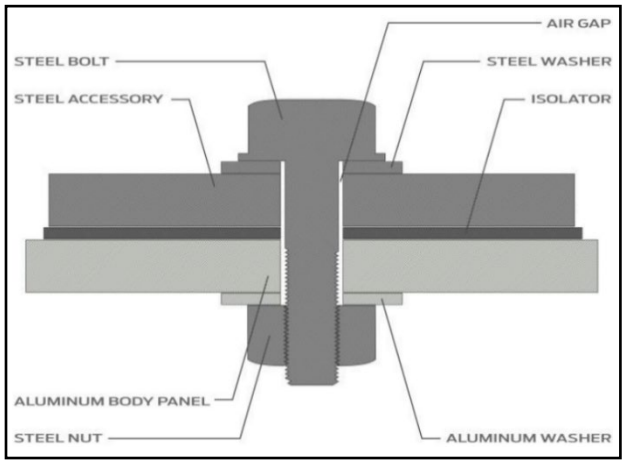



**Figure 2 - Steel Accessory**

Figure 1 shows a plastic accessory attached to aluminum sheet metal and the fastener properly isolated from contact with the aluminum sheet metal.

Figure 2 shows a steel accessory and steel fastener properly isolated from contact with the aluminum sheet metal.

Note: both figures show the fastener using an aluminum washer and having an oversize hole providing an air gap to the aluminum sheet metal.

Important: The items listed below can accelerate galvanic corrosion in aluminum and should be avoided. If a steel fastener must be used, it is necessary to properly isolate it from contact with the aluminum.

- self-tapping screws
- steel rivet nut
- steel blind pull-pin rivets
- steel spring clips
- RTV silicone
- stainless steel fastener

For Pickups with aluminum bodies: It is not recommended to make modifications or repairs that encroach on the “box to frame” or “cab to frame” interface.

When adding accessories that require an electrical ground to the chassis, follow the guidelines below.

- Only add ground cables to the sides of frame rails
- Do not add grounds to the Aluminum sheet metal

Attaching Accessories to Magnesium Structure

Similar to attaching to aluminum structure (see section above), attaching accessories to magnesium structural components requires careful isolation of dissimilar materials to prevent galvanic corrosion.

If using a steel fastener in contact with, or passing through magnesium, the following isolation methods are recommended:

- Steel bolt and/or nut is zinc coated
- 5052 Aluminum washers used to isolate the bolt or nut head.
  - The washer must be a minimum 0.5 mm thick, thicker washers are recommended when used on horizontal surfaces.
  - Diameter of the washer must be a minimum of 10mm larger than the diameter of the bolt or nut flange, or steel washer if one is used.
  - Stamping direction of the aluminum washer must be AWAY from the mating magnesium surface. This will prevent the stamping burr on the washer from scoring the magnesium base material or coating.
- A Nylon sleeve must be used on the neck of the bolt where it passes through the magnesium structure. Nylon material must have a carbon content less than 2% to prevent corrosion.

These precautions are meant to protect against water droplets from being in contact with the coated steel fastener and magnesium at the same time. Joints should also be positioned to minimize the chance of water pooling near the head of the fastener.

The materials and design criteria above are specified for steel fasteners but can be extended in a similar way to isolate steel accessories that are attached to magnesium components.

Headlight Alignment

Headlight initial aim is set at the assembly plant but may not be correct for your final vehicle configuration. Verification of headlight aim after installation of the SUB is the responsibility of the final stage manufacturer and should be part of the completed vehicle sign-off.

**Heat Management**

The following guidelines should be followed to ensure proper management of heat energy:

- Under body longitudinal or lateral air movement should not be restricted. Frame spacers designed by the intermediate and final stage manufacturer should provide for adequate airflow over the frame.
- No portion of the floor pan should drop below the body sills, nor should the under-body structure drop below the top surfaces of the chassis frame rails. These conditions can result in reduced airflow or pinched fuel lines or vapor hoses, which can raise the temperature of under body components and increase fuel system pressure.
- Second unit body exterior panels, tool boxes, running boards, structures, or skirting that extend below the bottom of the frame, may affect under body temperatures. The final stage manufacturer should verify that under body temperatures of the completed vehicle are compatible with all vehicle components during the projected vehicle duty cycle and vehicle loading.
- Full-width mud flaps should not be installed as they restrict airflow under the vehicle and can increase under body temperatures.
- Added structure or equipment should not restrict air circulation in the engine compartment.
- Use of wood in construction should be eliminated where at all possible. If used, wood should be adequately protected from moisture and heat. Shields should be added if wood is installed near exhaust components.
- It is not recommended to add any vent to the vehicle hood as a means to lower under hood temperatures. Depending on the location and orientation of added vents, they may cause hot air to be recirculated toward the radiator or cause hot air and/or undesirable fumes to be directed toward the climate control intake in the vehicle cowl.
- Underbody coatings should not be applied within 203.4mm [8 inches] of any exhaust component (more if the softening or running point of the coating material is less than 125°C). Coatings should not be applied directly above exhaust components (to prevent material dripping onto the exhaust) unless a proper drip shield is installed.
- Any interior floor underlayment, insulation or chassis mounted component within 101.6 mm [4 in] of the exhaust system, without benefit of the Ford provided heat shields, must be capable of withstanding 371°C [700°F] (482°C [900°F] in close proximity to the catalyst) during normal operating conditions.
- Paint and other coatings can cause excessive heat buildup or reduced performance if applied to sensitive components. Components related to the following systems should not be coated and should be protected from overspray when coating adjacent parts:
  - Engine system - including intake system, exhaust manifold, ignition components, fuel rail, electronics and sensors.
  - Transmission.
  - Cooling system – especially radiators.
  - Exhaust system and emissions control components.
  - Fuel tank and fuel fill/vent components.
  - Any heat shields or components near the exhaust system (within 8 inches).

The subsequent stage manufacturer should also consider the following situations, which may have an adverse effect on heat management:

- Poor vehicle service or lack of maintenance
- Deviation from a Ford recommended antifreeze coolant
- Exceeding Ford GVWR and GCWR ratings
- Altering, changing, removing Ford engine cooling fan and shroud
- Altering, changing, removing Ford heat shields, heat sleeves, and/or other thermal protection elements
- Blocked radiator grille area (spare tire, bicycles, etc.)
- Use of throttle kickers
- Addition of aftermarket PTO system

**Fuel System**

WARNING:
Before opening the fuel system, removing or re-installing any Ford fuel system component, relieve fuel pressure by following the instructions in the Ford Shop Manual for the appropriate model and model year. The evaporative emission system contains fuel vapor and condensed fuel vapor. Although not present in large quantities, it still presents a danger of explosion or fire. When welding near fuel system components, all metallic components should be adequately shielded and protected from heat or weld splatter. All non-metallic components should be removed.

When extending a vehicle wheelbase on vehicles equipped with a mid-ship fuel tank, the tank and fuel line system must remain in the same position relative to the OEM rear frame and axle assembly as originally designed. This requirement helps assure fuel system integrity and provides for optimum use of the OEM fuel system attaching components. This will require the modifier to develop and install a new forward cross member for supporting the mid-ship tank when the frame is lengthened.

Fuel Tanks

It is not recommended to modify the existing vehicle fuel tank. If a replacement or additional fuel tank is fitted, the following guidelines should be observed:

- The fuel tank should be designed with as few openings and connections as possible. Openings and connections generally should be located on the upper surface of the fuel tank.
- Fuel tanks should be fitted with an evaporation control valve having the means to close if the vehicle is rotated about a longitudinal axis.
- The tank should be of simple configuration minimizing sharp surface transitions and protrusions which may be required for attachment or function.
- The tank should be strong enough to withstand instantaneous internal pressure imposed during a crash event.
- Hoses connected to the tank should be sufficiently flexible to permit small movements of the tank relative to fixed mounting surfaces without rupture or disconnection of such hoses during a crash event.
- Emission regulations may require an OBDII fuel tank pressure sensor for the evaporative system. Any new fuel tank must be tested and comply with all emission regulations, including evaporative emissions.
- Package new tank away from heat sources such as exhaust.

Fuel Tank Retention Systems

It is not recommended to modify the existing vehicle fuel tank retention systems. If a replacement or additional fuel tank is fitted, the following guidelines should be observed regarding fuel tank retention:

- The retention system should attach the fuel tank to the frame between the frame rails and below the body of the vehicle with sufficient clearance for normal body to frame movement under loaded conditions.
- A retention system should restrict fuel tank movement in all possible directions to prevent contact or rupture with rigid or sharp objects, and the disconnection of fuel system tubes and hoses under crash conditions. Retention straps should avoid sharp edges and tank supports should be designed with fuel tank compatible surfaces and edges.
- System fasteners and attachments should be designed to retain the tank during deflections incurred during a crash event.

Fuel Fill System

The following recommendations should be followed regarding the fuel fill system:

- The fill system should be sufficiently flexible to prevent possible rupture or disconnection resulting from movement of the fuel tank relative to frame during crash situations.
- Any equipment or hardware attachments to the body in the area of a fuel system component should be designed, positioned, and secured so as not to impact any fuel system component during crash situations.
- The fuel filler opening area of the body should provide adequate sealing from the vehicle interior because holes or cracks in this area may allow fuel vapors to enter the vehicle interior. Openings should be sealed with a product which is fuel resistant. See Figure 3.

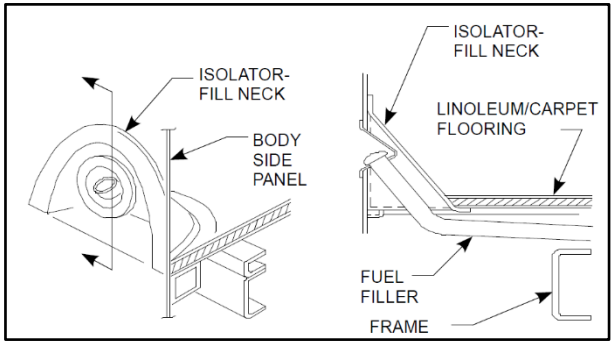



**Figure 3 – Body Mounted Fuel Filler Openings**

- The metal outer end of the fuel fill neck tube provided by Ford must be properly grounded to the chassis to dissipate any electrostatic charge that may be produced and reduce the possibility of a spark during fueling. A fill neck support made of metal would provide a ground path if directly mounted on the chassis. If the filler neck support is made of plastic or other non-metallic material, a ground strap or wire must connect the metal end of the fuel filler neck and a metal chassis component.
- Fill openings should be recessed, and caps, when installed, should be inside the normal body plane.
- Whenever possible, the fill system should pass under the body rather than through it. Where passing through floors and sides, the fill system should be shielded and have adequate clearance to surrounding structure. Fuel Filler and Vent Hoses should maintain clearance to body and surrounding chassis components. See applicable vehicle IVM for further details.
- Be sure that the fuel tank filler cap is the correct Ford designated part. Provide adequate hand clearance for cap installation and correct sealing of the cap to filler pipe.

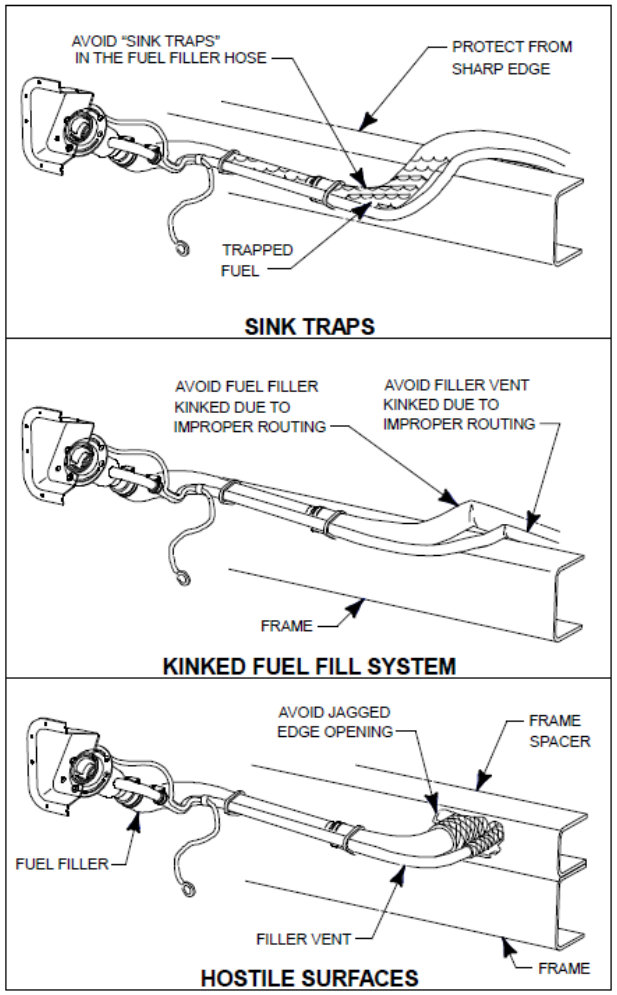



**Figure 4 – Fuel Fill System Installation**

- The acceptable horizontal and vertical locations for the fuel tank filler pipe are shown in the appropriate vehicle specific IVM for Incomplete Vehicles and in the program specific BBLB for Box Removal vehicles.
- When installing accessories or equipment, avoid exposure of fuel and vapor hoses to surfaces with sharp edges (see "Hostile Surfaces", Figure 4) or high temperature surfaces (near hot exhaust or coolant). Also avoid installations which result in the exposure of these lines to road debris or undercoating.
- Install or route fuel tank filler hoses and filler vent hoses as follows:
  - Keep the flow of fuel continuously downward from the inlet of the fuel filler pipe all the way to the tank. See "Sink Traps" in Figure 4. Fuel trapped in low spots can be expelled when the cap is removed, even if the tank is nearly empty.
  - Avoid pinches or kinks as they may restrict fuel filling and venting. Hose length may require adjusting depending on second unit body width. See "Kinked Fuel Fill System", Figure 4
- Do not place adjacent hardware such that it may cut or otherwise damage the filler neck or vent hoses and cause fuel or vapor leakage. See Hostile Surfaces, Figure 4.
- The fuel fill hose and vent hose must be clear of moving suspension components to prevent abrasion which can result in fuel leakage.
- Be certain that all clamps are secure and properly located.
- The fuel fill and vent hoses should not contain fittings or connections other than those incorporated in the original design, nor should they be interconnected with each other in any way.
- Only Ford approved parts should be used.

Fuel Lines, Hoses and Pumps

The following recommendations should be followed regarding fuel lines, hoses and pumps:

- Do not reroute or change the attachment of fuel lines or fuel vapor hoses. Doing so may adversely affect vehicle performance by increasing the amount of heat absorbed by the fuel system or by restricting its venting.
- Tubes and hoses should be routed away from and not attached to members that will move or deform during crash situations.
- Tubes and hoses must be sufficiently flexible to avoid rupture or disconnection resulting from movement of the engine relative to the frame during crash situations.
- Tubes and hoses should be routed away from hot regions and sharp objects and should be retained adequately to prevent movement into such regions or against such objects.
- Do not add fuel or vapor line flow restrictors as they can cause engine fuel starvation or abnormally high fuel tank pressures.
- Do not install auxiliary fuel pumps. This could cause the engine to run rich, producing additional exhaust heat.
- The special removal tool shown in Figure 5 must be used to open push connectors installed on flexible fuel lines, if the lines need to be disconnected. The appropriate tool is available from Ford Customer Service Division.
- The push connectors on flexible fuel lines, if disconnected, must be reconnected by snapping them back into position and installing the appropriate retainer as shown in Figure 5.
- Avoid pinching or kinking of any fuel vapor hose. (See Figure 6).
- Each of the fuel lines and fuel vapor hose retention clips provided by Ford must be used in original factory locations to prevent misplacement or movement of the lines.

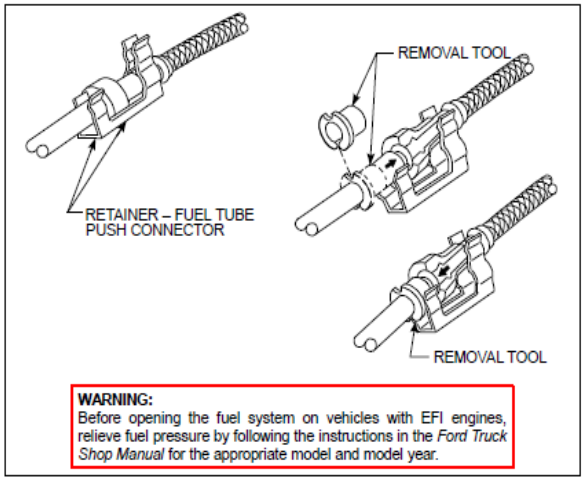

REMOVAL TOOL
RETAINER – FUEL TUBE
PUSH CONNECTOR
REMOVAL TOOL
WARNING:
Before opening the fuel system on vehicles with EFI engines, relieve fuel pressure by following the instructions in the Ford Truck Shop Manual for the appropriate model and model year.

**Figure 5 – Flexible Fuel Line Push-Connect**

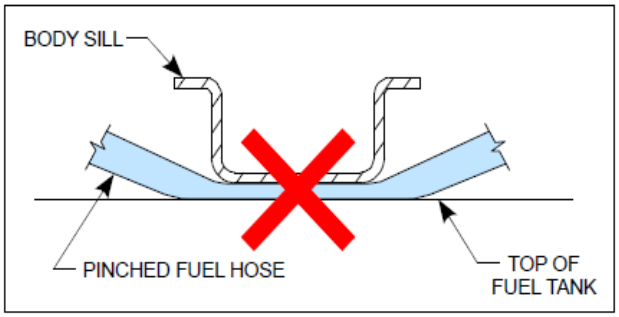



**Figure 6 – Pinched Fuel Vapor Lines**

- Be certain that the vent valves on top of the fuel tanks are seated and secure; do not dislodge or damage them when mounting the second unit body. If they are unseated, fuel leakage may occur. If damaged, the vapor vent system may not function, resulting in increased fuel tank pressure.
- If a fuel sender is removed for any reason, use a new gasket when it is reinstalled to prevent fuel leaks. Be certain the fuel sender is seated and secure on the top of the fuel tank. Do not step on or place weight on the sender during vehicle manufacture.
- Fuel filters installed in the fuel supply line must be of sufficient size to be nonrestrictive to fuel flow and placed to be protected from exposure to exhaust heat and physical damage. Ford replacement fuel filters are recommended. Filters are not to be installed in the fuel return line.
- Temporary shipping fuel lines are not to be reused. They should be recycled where possible or disposed of in an appropriate manner.
- Fuel system components which are disconnected during manufacturing should be capped or plugged promptly to prevent possible contamination.
- If fuel vapor lines need to be modified, they should be removed from the vehicle prior to being altered. If cutting the lines, debris from cutting should be minimized and immediately removed from the hose. All open ends should be promptly capped until the hose is reassembled to reduce potential for contamination.
- When welding near fuel system components, all metallic components must be adequately shielded and protected from heat or weld splatter. All nonmetallic components must be removed.
- Changing the length of a fuel line can consist of either replacing the intermediate fuel line assembly with a new assembly of different length, or adding a fuel line extension. Cutting and splicing of metal fuel tubes or braided flex lines is unacceptable. Fuel line extensions or modified length replacement lines should meet the following standards at a minimum:
  - Connectors - SAE J2044
  - Tubing - SAE J2260
  - Assembly - SAE J2045
- It is recommended that any flexible line extensions allow approximately one inch of additional length, in excess of the nominal length, to provide for routing and installation ease. This additional length will avoid a stretch-to-fit situation when reconnecting the fuel lines.
- Any fuel lines which have been kinked must be replaced.
- Do not allow any flexible fuel lines to coil or otherwise be routed outside of the frame side rail section. Fuel routings should remain inside the frame side rails, similar to the OEM routings, and be secured to the frame for maximum protection and safety.
- Secure all added fuel lines to the frame with clips and clip spacing consistent with the original fuel line routing.
- Evaporative system lines must not be kinked or routed in a manner which could cause them to collapse. Retention of evaporative lines must be consistent with the original line clip types and spacing. Extensions must made of material similar to the original equipment.
- Inspect the installation for possible chafe and rattle condition with the frame, fasteners, and other lines.
- Do not coil or bend the braided flex line tighter than a five-inch diameter. Excessive bending or mishandling can result in fuel hose kinks and permanent damage.

Fuel System Access for Auxiliary Fuel Powered Equipment

Precautions similar to those described in this Fuel System section should be taken in the design and positioning of a fuel system for auxiliary fuel-powered equipment. The auxiliary fuel-powered equipment should be securely mounted to withstand forces during crash situations.

Final stage manufacturers or alterers utilizing the auxiliary fuel port must install an electrically actuated, normally closed solenoid valve into the fuel line leading to the auxiliary fuel powered equipment. The valve should remain open during the start and run cycle of the auxiliary equipment and must close immediately when the auxiliary equipment is turned off or is out of fuel.

If auxiliary fuel powered equipment is capable of operating while the vehicle is being driven, it is recommended to use the Upfitter Interface Module (where available) to control the aux fuel solenoid valve. Logic can be programmed (using the “Crash Event Status” signal, in conjunction with other vehicle signals and upfitter defined inputs) to provide proper equipment operation during normal vehicle usage and to shut off the aux fuel valve in a crash situation. See the *Design Recommendations -> Electrical System -> Upfitter Interface Module (UIM)* section for more information on the UIM and how it can be utilized.

All auxiliary fuel ports have a safety cap which must remain in place until a fuel consuming accessory is installed. It is recommended that all components related to auxiliary fuel equipment follow the guidance provided in the *Fuel Lines, Hoses and Pumps* section where applicable.

See appropriate program specific BBLB for more information regarding the location and use of auxiliary fuel ports where provided.

**Electrical System**

Transport Mode

After a new vehicle is built, some modules are set in “Transport Mode”, which disables or alters various systems to reduce battery drain. The vehicle message center displays “Transport Mode Contact Dealer” while in this state. The vehicle will automatically progress to normal operation after it has been driven 125 miles (201 km), or it can be manually advanced by the following procedure:

1. Start with a fully charged battery and ignition in the OFF position
2. Place the ignition in the ON position
3. Press and release the brake pedal 5 times
4. Press and release the hazard switch 2 times

Note: Step 3 and 4 must be carried out within 10 seconds. The vehicle message center indicates “Normal Mode” when the process has been successfully completed. Once in Normal Mode, Transport Mode cannot be restored.

Module Configuration / Calibration

Most Ford Truck Vehicle Lines have electronic modules that are configurable during subsequent manufacturing stages to accommodate a wide range of upfits. On some vehicles, the final stage manufacturer is responsible for verifying that module calibration is valid on completed vehicles (e.g. Incomplete vehicles with Lane Keeping Assist (LKA) feature - calibration of forward-facing camera needs to be performed on the completed vehicle). In any case, a Ford service scan tool (IDS/FDRS) will be required to perform updates to vehicle electronic systems. Procedures to revise configurations and calibrations can be found in the appropriate vehicle workshop manuals. Upfitters that do not have their own service scan tool can leverage their local Ford dealer for assistance, for a fee set by that dealer.

Note: Module configuration and/or calibration is not included with the new vehicle purchase or as part of any warranty program.

General Practices

Note: See program specific BBLB documents for recommended electrical connection points for commonly installed equipment.

Note: When the battery cables are disconnected from the battery, the PCM, radio, and other memories will be lost. The vehicle's engine performance and transmission shift schedule will also be affected until the Powertrain Control Module (PCM) "relearns" the lost data. This action usually requires a few miles of normal driving.

Prior to arc welding or plasma cutting on the vehicle, disconnect the battery's negative (ground) cable(s) and ALL connectors leading to sensitive modules (PCM, BCM, ABS, Instrument Cluster, GPM, NOx, SCR, TCM etc.). Disconnecting the battery cable(s) alone is not enough to prevent damage to electronic modules.

Be cautious when connecting and disconnecting electrical connectors to avoid damage to contact pins and contamination in the connector interface.

It is strongly recommended that wiring in areas of heavy rework, or in areas where welding operations are to be performed, be removed prior to the rework operations and reinstalled after the rework is completed. If wire removal is not practical, the wires must be shielded from damage due to the rework and welding heat. All components and wiring should be reinstalled as closely as possible to the original factory installation.

Prior to any alterations of the vehicle electrical systems, the battery's negative (ground) cable(s) must be disconnected and positioned to prevent re-contact with the negative post. This precaution will minimize the potential for dead batteries and possible damage to vehicle circuitry.

Do not modify the OEM wiring to the Powertrain Control Module (PCM).

Do not splice into the stop lamp switch as this can interfere with the proper functioning of PCM, speed control, and anti-lock brake electronic modules.

The vehicle Ignition circuit should not be altered.

Modification to the OEM starting system or wiring is not recommended.

An electrical load analysis must be performed prior to adding loads to existing OEM fused circuits. The total circuit current draw (including additional load) must not exceed 80% of the OEM circuit current protection rating for fuses located in the passenger compartment and 60% of the OEM circuit current protection rating for fuses in the engine compartment.

Be very cautious not to exceed the circuit limitations when driving additional electrical load directly from a Body Control Module (BCM) output. It is preferred to use the BCM output to drive an auxiliary relay coil if there is any question whether the BCM driver is adequate for the application. If the BCM driver is overloaded, the output may be temporarily disabled or permanent damage may occur to the BCM, requiring its replacement. Relay selection is important and depends on current requirements, number of cycles expected in the relay lifetime, whether the relay is to be operated intermittently or for long periods of time, and whether the relay is exposed to weather conditions or is installed in a protected area. When the current requirements of a circuit exceed the capacity of an available relay, more than one relay can be used if the circuit is wired to split the load.

When adding circuits with higher demands than the host OEM circuit can provide, relays should be incorporated into the system. The OEM wiring may be utilized as a signal source for the relay coil. Power to the added circuit should be supplied directly from the vehicle battery or additional aftermarket battery(s) through the relay.

All installed equipment that utilize electric motors should have a discharge path for the reverse voltage generated by the motors when power is turned off. Failure to provide a discharge path can result in damage to other electrical equipment installed by the modifier or Ford Motor Company. Resultant damage to Ford electrical devices may not be repaired under warranty. The equipment manufacturer can provide information about the presence of a discharge path on their electric motors.

Any added alternator must be Ford OEM or equivalent. Modifications to vehicle charging systems must be done

in a manner that does not cause electrical overload of the OEM wiring, overcharging of batteries, etc. Consult the Ford Truck Body Builders Advisory Service prior to incorporating any charging system modification.

Do not move, alter, or add circuits to OEM electrical ground points. Do not ground the body to the transmission or transmission cross member. Ground the Second Unit Body to the frame in at least two locations, and if required, add an additional frame to engine ground cable to improve the ground path to the battery.

After all electrical or vehicle modifications, perform the on-board diagnostics procedures as described in the powertrain control/emissions diagnosis manual to clear all diagnostic trouble codes (DTCs). In addition, perform self-test to the BCM and test all lighting outputs. Road test vehicle and rerun the on-board diagnostics to verify that no DTCs are present. If DTCs are generated, perform the appropriate diagnostic procedures and repairs. Vehicle operation (engine, transmission, and lighting) may be affected if DTCs are not serviced.

Accessing Power

Some Ford vehicles are equipped with conveniently located electrical wiring taps. Most taps are fused, having locations under the instrument panel, in the engine compartment, and/or at the rear of the frame. Program specific BBLBs will provide details on the locations and limitations of these circuits, if provided.

Do not tap (piggyback) into either side of any fuse in the OEM interior fuse panel or under-hood power distribution box, or splice into any power circuit that feeds into either one of these components.

The power supply wire for added circuits from the battery should be properly sized, include appropriate fusing, and should be connected as follows:

- For circuits requiring a maximum total of 30 amperes, make the connections at the starter motor relay's positive terminal, not at the battery terminal. This will aid battery serviceability.
- For circuits requiring more than 30 amperes, make connections directly to the battery's positive terminal. Route the wire along the battery cable to provide a neater wire routing and assist battery serviceability.

Caution – When connecting devices to the battery, extreme caution must be taken to maintain clearance between any conductive surface connected to the B+ terminal and any surrounding conductive materials (such as the hood inner panel). Any reduction in clearance between components as provided by Ford or as described in the vehicle IVM or BBLBs may result in an electrical short (or arcing), which may lead to failures in the electrical system or result in fire.

All current load added by body builders should be evaluated for key off loads. If possible, a supply for the load should be ignition key controlled (i.e. RUN only, RUN/START only, etc.). Powered equipment should be evaluated for operation in different operation modes (Transmission in Park, Parking Brake set, etc.). If the operation of the equipment is to be limited to specific operation modes, the power source should be active during the operational mode(s) only.

Key Off Loads

A key off load is defined as a current draw on the battery when the ignition key switch is in the off position. Key off loads are important because they will lower the charge in the battery between vehicle uses.

The key off amperage draw of all equipment connected to the vehicle's main or multiple batteries should not exceed 28 milliamps. If equipment inclusion into the vehicle's electrical system would cause the amperage draw to exceed 28 milliamps, the equipment should be connected to an auxiliary battery or an isolated battery bank.

Hall Effect Sensors are commercially available sensors that detect the magnetic field generated in a wire when electrical current passes the sensor. The sensor allows for determination of the amount of current in the wire without altering the wire. The best practices solution for reading large currents (>20 mA) is utilization of a Hall Effect sensor.

Steady state Key Off Load can be determined utilizing one of the following methods:

Method 1 (Preferred) - Hall Effect sensor

1. Ensure that the vehicle is not in “on” or “accessory” key state and the delayed accessory feature is not active (wait 15 minutes).
2. Connect the Hall Effect sensor to the negative battery cable.
3. Read the current on the Hall Effect sensor's meter. This is your key off load.

Method 2 - Ammeter

1. Ensure that the vehicle is not in “on” or “accessory” key state and the delayed accessory feature is not active (wait 15 minutes).
2. Remove the negative battery terminal from the battery post.
3. Connect an ammeter in series with the negative battery terminal and the negative pole of the battery.
4. Read the current on the ammeter. This is your key off load.

Use of a Hall Effect sensor prevents memory loss in the Powertrain Control Module (PCM) and the radio. Use caution with Hall Effect / Clamp On current meters, many are not sensitive enough to accurately register between 10 and 30 milliamps. In addition, small movements of the meter along the wire may cause large differences in readings.

Battery Relocation

Battery cables should not be spliced. A new, non-spliced, cable should be installed.

Appropriate battery hold-down brackets must be used to retain batteries from shifting.

The hold-down system must allow for a minimum 1" (25 mm) air gap between adjacent batteries.

The battery ground lug and the red positive jumper cable lug must be relocated to a similar position adjacent to the new battery location.

See the “Electrical Wiring – Wire Gauge” section for more information on battery cables.

Auxiliary Batteries vs. Multiple Batteries

An auxiliary battery is defined as a battery that is relay isolated from the primary battery and the alternator. This battery is intended to provide power to “key off” loads (see “Key Off Loads” section for definition) without loss of the primary battery's starting capability. Only circuits that are required to be “Hot at all times” or have significant key off load should be connected to an Auxiliary Battery.

Multiple batteries are defined as two or more batteries being charged from the vehicle's alternator that are electrically in parallel with each other. Utilization of multiple batteries can provide significant power for short periods of time. This power output may even occur at low engine rpm's without adversely affecting the electrical system of the vehicle. Utilization of a wheelchair lift, or a snow plow are good examples of such an application.

The utilization of high current (40 Amps or more) "Key On" loads should be handled with a multiple battery alternative rather than an isolated battery.

The 6.7L diesel engine requires two batteries wired in parallel for proper starting operation and must not be isolated.

Fusing and Circuit Protection

Added electrical circuits should be protected by a fuse or circuit breaker, labeled, and positioned to facilitate servicing. Fuses and circuit breakers located in the engine compartment should be sealed to minimize corrosion.

The protection device should be installed as close to the point of tapped power as possible.

Never increase the rating of a factory installed fuse or circuit breaker.

Electrical Wiring - General

All added wiring should be color coded or labeled to aid in identification during service.

All added under hood and under body wiring must be cross linked polyethylene, high temperature (minimum 125 °C) insulated wire. SAE Specification J1128 SXL, GXL, or TXL wire or equivalent is acceptable. Use SAE J1127 SGX or STX or equivalent for battery cables. Interior wiring not exposed to high temperatures may be SAE approved, general purpose wire. See the “Definitions” section for the definition of the terms Under Body and Under Hood.

All added under hood and under body wiring should be protected with high temperature (minimum 125 °C) nylon convoluted tubing.

Connectors, splices and eyelets in the engine compartment, under body or in "wet" areas of the passenger compartment are recommended to be sealed to prevent corrosion and short circuits. Ground the second unit body to the frame in at least two locations, and if required, add an additional frame to engine ground cable to improve the ground path to the battery.

| WIRE GAGE TABLE | |
|---|---|
| Wire Gage | Maximum Current Capacity (Plastic Insulated Copper Wire) |
| 20 | 10 Amps |
| 18 | 15 Amps |
| 16 | 20 Amps |
| 14 | 25 Amps |
| 12 | 30 Amps |
| 10 | 40 Amps |

**Figure 7 – Wire Gage Table**

Electrical Wiring - Wire Gage

When adding wiring, the wire gage should be determined as follows:

- Where wire is spliced to extend a circuit, the added wire should have a gauge at least that of the circuit being modified.
- When circuits are added to feed aftermarket devices, the wire gage of the circuit should be determined by referencing the Wire Gage Table (Figure 7). NOTE: The current capacity of a given wire varies with temperature and type of insulation. The table, however, represents generally accepted values as a guide.
- The replacement or extension of any cable from the batteries or alternators must not increase the voltage drop in the circuit. This can be accomplished by increasing the wire gauge, or by adding a parallel cable. Do not modify the alternator battery sense ("A") line circuit. In order to reduce the possibility of environmental conditions resulting in increased starting voltage drop, all battery cable connections should be coated with a corrosion protectant after all connections are torqued. Note: Cables in parallel must have appropriate terminals on each end to assure full current carrying capacity of the pair.

Electrical Wiring - Routing & Retention

Wire routings of installed components or wire routing revisions of the Ford harnesses necessitated by reworks must conform to the following:

- Wires routed through holes in sheet metal or castings must have the edges of holes protected by a grommet. Use customer access pass-thru circuits where provided to avoid additional openings between passenger and engine compartments.
- Wires should be routed to avoid metal edges, screws, trim fasteners and abrasive surfaces. When such routings are not possible, protective devices (shields, caps, convoluted tubing etc.) must be used to protect the wires. When wires must cross a metal edge, the edge should be covered with a protective shield and the wiring fastened within 3 inches of the edge.

- Wires must be routed to provide at least 3 inches clearance to moving parts, unless positively fastened or protected by conduit.
- All seat wiring should be properly routed and properly anchored away from any unfriendly surface such as sharp edges and moving parts of the seat track mechanism.
- Existing heat shields, insulation, and wire shielding/twisting must be maintained.
- When wiring is routed between two members where relative motion can occur, the wiring should be secured to each member, with enough wire slack to allow flexing without damage to the wire.
- Wiring to all circuit components (switches, relays, etc.) in exposed locations must provide a drip loop to prevent moisture from being conducted into the device via the wire connection.
- Wiring should not be routed through wheel well areas where they may be damaged by tire or road debris, snow packing, excess water etc. When such routings cannot be avoided, adequate clipping or protective shields are required.
- The wire retainers and grommets installed by Ford are usually designed to accommodate only the Ford-installed wires. Additional wiring or tubing should be retained by additional clips.
- All wiring connections to components of the factory-installed system must be accomplished by using the proper mating wire termination. (Connections on studs and ground connections must use eyelet terminations, connections to female bullets must terminate in male bullets, etc.)
- Transmission of electrical power through a wire will generate an electro-magnetic field around the wire. Wires carrying low power signals may experience induced electric noise in excess of the low power signal if they are near a high-power transmission wire. For this reason, high power transmission wires should be routed away from any OEM harnesses. The spacing should be maximized and should never be less than 12 inches (304.8 mm) for battery voltage or one inch (25.4 mm) per volt. Higher voltage alternating current (AC) circuits may require twisted pair or grounded shielding to allow their placement on the vehicle without affecting other circuits.
- All wiring should be protected from fastener damage during the build process (e.g. pinched underneath fastener head, or contacted by backside of fastener extending from joint)
- The use of generic plastic cable ties (aka zip ties) should be limited to bundling the harnesses.

In addition, for all added under hood and under body wiring:

- Electrical wire should not contact, or attach to, fuel or brake lines.
- Engine compartment wiring must not be rerouted in any manner.
- Added wiring should be located to avoid, or secured away from, rotating or otherwise moving parts (i.e. cooling fans, engine belts, transmission shift controls, brake or accelerator controls, etc.).
- A minimum clearance of 231 mm [6 in] should be maintained from exhaust system components. Where compliance with this requirement is not possible, heat shields are required.
- A minimum clearance of 38 mm [1.5 in] should be maintained from the engine.

Electrical Wiring - Splice / Repair

When necessary to splice wire for repair or circuit length revisions, the following guide should be followed:

- When stripping wire ends, make sure that individual conductor strands are not damaged.
- When soldering, make sure an adequate mechanical joint exists before applying solder. Use only rosin core solder — never acid core.
- For crimp joints, use butt-type metal barrel connectors and a proper tool (such as Motorcraft crimp tool S-9796) specifically designated for this type of work.
- Splice joints must be adequately sealed and insulated. Adhesive-lined heat shrink tubing is highly recommended to cover soldered and bare metal barrel crimp joints.
- The most durable splice joint will be bare metal, barrel crimped, flow-soldered and covered with adhesive lined heat shrink tubing. This is recommended as the preferred splice joint.
- Heat shrink tubing is effective in preventing strain breakage of small gauge wire (20-22 gauge).
- When splicing or extending the anti-lock brake system (ABS) twisted pair SXL wiring, the OEM specification of one full twist per inch must be maintained as originally provided.
- Battery and Alternator wiring should not be spliced. If these circuits need to be modified, new wire should be used.

Lighting

Incandescent bulb charts are provided in this document (Figure 8) to assist in determining lamp loads.

The Light Emitting Diode (LED) can be used to replace incandescent bulbs. The higher cost of LEDs can be offset by the long life and reduced energy use compared to incandescent bulbs. The low current requirement of LED displays does cause some circuits to perceive a bulb out condition. This situation can be corrected by reconfiguring the BCM to disable bulb outage detection on some vehicles.

Another issue that can be caused by using LED lighting on circuits designed for incandescent bulbs is an intermittent flickering of the installed LED display. Many circuits intended for incandescent bulbs use Pulse Width Modulation (PWM) to optimize bulb life. PWM is the rapid switching on and off of a DC voltage source to lower the effective voltage supplied to a component. The frequency with which the PWM control cycles on and off is set significantly higher than the “reaction” time of an incandescent bulb to the change in voltage, so that the light output of the incandescent bulb is perceived as “steady”. LED displays respond much more quickly to changes in line voltage than do incandescent bulbs, which can result in a high frequency flicker of the LED when PWM is active. In many cases the Body Control Module (BCM) can be reconfigured from PWM to direct current circuit control to prevent this condition. See the program specific BBLB for details on lighting circuit configurability.

When adding Stop Lamp or CHMSL lighting elements to a vehicle, be sure to only use circuits recommended in the program specific IVM or BBLB. Many vehicles are

equipped with Advanced Emergency Braking Systems (AEB) where the vehicle system can apply the brakes without input from the driver. If circuits other than those recommended are used for stop or CHMSL lamps, there is a chance that the lamps will not illuminate during AEB (non-driver initiated) braking events.

Incandescent Electrical bulb types used in a vehicle are listed in the Owner's Manual Bulb Chart. For replacement bulbs, check for the "DOT" marking on the bulb base which means the bulb meets U.S. "DOT" standards. Use of bulbs without the "DOT" marking or that produce different colors other than the original bulbs as listed in the bulb chart may affect the lamp's light output, aim, glare and your safety; in addition, such bulbs may burn out early or damage the lamp

## BULB CHARTS

| BULB TRADE NUMBER | CANDLE POWER | CURRENT @ RATED VOLTAGE |
|---|---|---|
| 67/97 | 4 | 0.69 A @ 13.5V |
| 168 | 3 | 0.35 A @ 14.0V |
| 192 | 3 | 0.33 A @ 13.0V |
| 194 | 2 | 0.27 A @ 14.0V |
| 211-2 | 12 | 0.97 A @ 12.8V |
| 212-2 | 6 | 0.74 A @ 13.5V |
| 578 | 9 | 0.78 A @ 12.8V |
| 579 | 9 | 0.8 A @ 12.8V |
| 904 | 4 | 0.69 A @ 13.5V |
| 904NA | 5.3 | 0.69 A @ 13.5V |
| 906 | 6 | 0.69 A @ 13.5V |
| 912 | 12 | 1.0 A @ 12.8V |
| 916 | 2 | 0.54 A @ 13.5V |
| 916NA | 1.5 | 0.54 A @ 13.5V |
| 921 | 21 | 1.4 A @ 12.8V |
| 922 | 15 | 0.98 A @ 12.8V |
| 1157A (major) | 24 | 2.1 A @ 12.8V |
| 1157A (minor) | 2.2 | 0.59 A @ 14.0V |
| 3057 (major) | 32 | 2.1 A@ 12.8V |
| 3057 (minor) | 32 | 2.1 A @ 12.8V |
| 3057K (major) | 32 | 2.1 A @ 12.8V |

| BULB TRADE NUMBER | CANDLE POWER | CURRENT @ RATED VOLTAGE |
|---|---|---|
| 3057K (minor) | 2 | 0.48 A @ 14.0V |
| 3155K | 21 | 1.6 A @ 12.8V |
| 3156 (P27W) | 32 | 2.1 A @ 12.8V |
| 3157 (P27/2W) (major) | 32 | 2.1 A @ 12.8V |
| 3157 (P27/2W) (minor) | 3 | 0.59 A @ 14.0V |
| 3157A (major) | 24 | 2.1 A @ 12.8V |
| 3157A (minor) | 2.2 | 0.59 A @ 14.0V |
| 3157K (major) | 32 | 2.1 A @ 12.8V |
| 3157K (minor) | 3 | 0.59 A @ 14.0V |
| 3456K | 40 | 2.23 A @ 12.8V |
| 3457AK (major) | 30 | 2.23 A @ 12.8V |
| 3457AK (minor) | 2.2 | 0.59 A @ 14.0V |
| 3457K (major) | 40 | 2.23 A @ 12.8V |
| 3457K (minor) | 3 | 0.59 A @ 14.0V |
| 3757AK (major) | 24 | 2.1 A @ 12.8V |
| 3757AK (minor) | 2.2 | 0.59 A @ 14.0V |
| 4057K (major) | 32 | 2.23 A @ 12.8V |
| 4057K (minor) | 2 | 0.48 A @ 14.0V |
| 4157K (major) | 32 | 2.23 A @ 12.8V |
| 4157K (minor) | 3 | 0.59 A @ 14.0V |
| W5W | 4 | 0.4 A @ 12.0V |

| HALOGEN BULB TRADE NUMBER | CANDLE POWER | WATTS @ RATED VOLTAGE |
|---|---|---|
| H1 | 117 | 55W @ 12.0V |
| H3 | 121 | 55W @ 12.0V |
| HB2 (9003) (low) | 76 | 55W @ 12.0V |
| HB2 (9003) (high) | 125 | 60W @ 12.0V |
| 9005 (HB3) | 135 | 65W @ 12.8V |
| 9006 (HB4) | 80 | 55W @ 12.8V |
| 9007 (HB5) (low) | 80 | 55W @ 12.8V |
| 9007 (HB5) (high) | 107 | 65W @ 12.8V |
| H13/9008 (low) | — | 55W @ 12.8V |
| H13/9008 (high) | — | 65W @ 12.8V |
| H7 | 125 | 55W @ 12.0V |
| H9 | 167 | 65W @ 12.0V |
| H11 | 107 | 55W @ 12.8V |
| H6054 (low) | — | 55W @ 12.8V |
| H6054 (high) | — | 65W @ 12.8V |
| 9140 | 48 | 40W @ 12.8V |
| 9145 (H10) | 65 | 45W @ 12.8V |

**Figure 8 – Bulb Chart**

Upfitter Interface Module (UIM)

The Upfitter Interface Module (UIM), also known as Programmable CAN Interface Module (PCIM), is an electronic control module that provides read-access to vehicle information for the purpose of programming output signals to control added equipment such as lift buckets, cranes, motors, salt spreaders, snow plows, etc. It is available as an option on Ford truck models shown in Figure 10. The UIM can also read numerous signals from the upfit system, as provided by the upfitter. All input signals can be utilized to create programmable logic to generate output signals to the upfitter body system, see Figure 8.

Several informational videos are available showing examples of how the UIM may be used to help control added equipment. These videos can be accessed via the Ford Body Builders Advisory Service (BBAS) website at https://fordbbas.com under "Publications". Expand the "Videos" Section to view all available video links.

The UIM outputs are intended as control signals only and are not to be used to provide power directly to equipment. New circuits with external relays must be installed to drive any added equipment.

The UIM does not come pre-programmed for use, it must be configured by the Upfitter using the Project Editor software. See Figure 9 for information on how to obtain the Project Editor software and associated instructions. The UIM Project Editor is compatible with Windows 7 and Windows 8 Operating Systems.

The UIM Project Editor allows the user to program the application logic for each UIM output based on UIM inputs and Vehicle CAN signals. A standard Type B USB 2.0 cable (not included) is required to connect the user's PC to the UIM in order to download the Project Editor application logic to the UIM. The upfitter-created application logic may be uploaded to the UIM while it is mounted in the vehicle or not (i.e. on a workbench).

Figures 11, 12 and 13 provide information on UIM electrical connections. Pin assignments and wire colors for UIM / PCIM connectors C1 and C2 and the supplied wiring harness are provided in the "UIM Owner Guide" for Gen 1, and in the "PCIM User's Guide" for Gen 2.

The UIM Gen-1 reads a wide variety of CAN signals (see Figure 14) from the vehicle in which it's installed. The UIM Gen-1 also can read up to 10 input signals (9 configurable as either "high" or "low") from the upfitters installed body system (from proximity sensors, etc.). All these signals can be programmed in the Project Editor to generate up to 15 output signals (8 "high" and 7 "low").

The UIM (PCIM) Gen-2 reads all of the CAN signals of the Gen-1 (see Figure 14) plus the additional signals shown in Figure 15. The UIM Gen-2 also can read up to 11 input signals (9 configurable as either "high" or "low") from the upfitters installed system (from proximity sensors, etc.). All these signals can be programmed in the Project Editor to generate up to 15 output signals (8 "high" and 7 "low").

If you have questions or need assistance with the Ford Fleet Website, contact the Ford Fleet Customer Information Center:

Telephone
1-800-34-FLEET (1-800-343-5338)
Monday-Friday
8:30 AM-5 PM EST

Email
http://www.fleet.ford.com/contact-us/customer-information-center/email-us/

NOTE: Ford Motor Company is not responsible for debugging or verifying the function of the customer-created UIM program files. It is the responsibility of the upfitter to ensure proper function of the software created to complete their upfit.

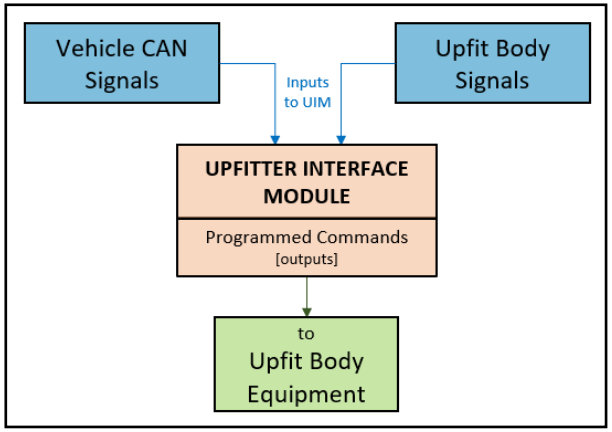



**Figure 8 – UIM / PCIM Flow Chart**

Gen-1 UIM Page Link

https://www.fleet.ford.com/partsandservice/upfitter-interface/

You need to be logged in to the Ford Fleet site to access the files. [Remember to click on "Ford UIM Terms of Use" and "Agree"]

The following files are available:
- "Read Me First"
- User Manual (for Project Editor Software)
- Owner Guide (for UIM module)
- Project Editor Program (for programming the UIM)

Gen-2 UIM / PCIM Page Link:

http://www.etis.ford.com/help.do

The following files are available:
- PCIM User's Guide
- Project Editor Software (for programming the PCIM)
- Project Editor Installation Guide
- Project Editor User's Manual

**Figure 9 – UIM / PCIM Links to Available Documents**

| Vehicle | Gen 1 UIM | Gen 2 UIM / PCIM |
|---|---|---|
| F250 - F550 Super Duty | 2017 MY + | N/A |
| F650 - F750 Medium Duty | N/A | 2021 MY + |
| Transit * | N/A | 2020 MY + |
| E-Series | N/A | 2021 MY + |

* UIM not available on Transits with split-view camera.

**Figure 10 - UIM / PCIM Availability Chart**

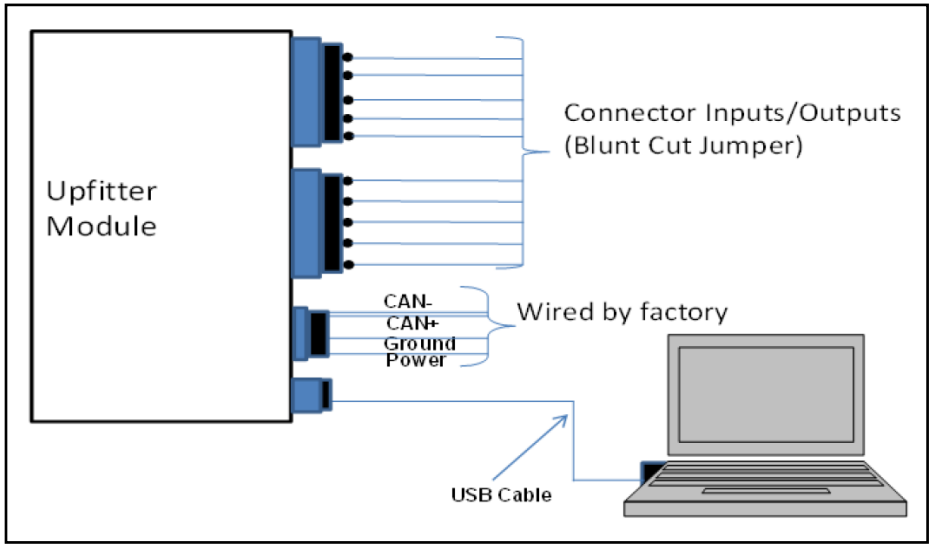



**Figure 11 - UIM / PCIM Schematic**

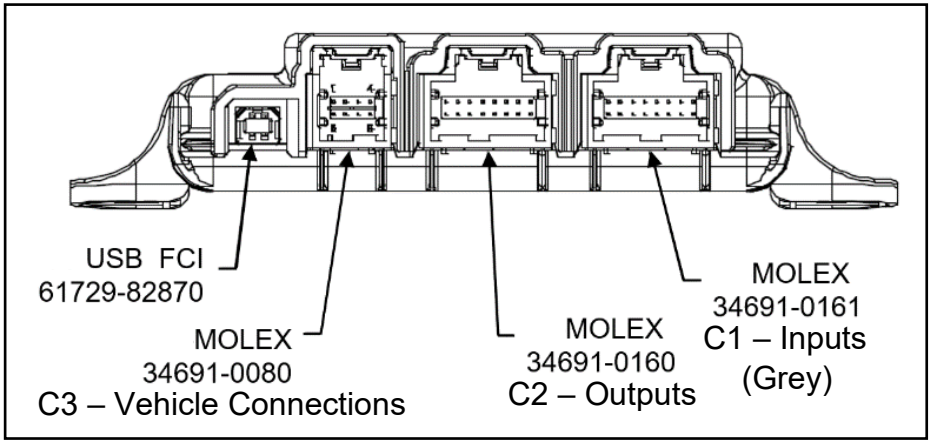



**Figure 12 - UIM / PCIM Connector Information**

**USB 2.0 Cable (Type B)**
[Provided by Upfitter]

**Blunt-cut Jumper**
For UIM / PCIM

**Figure 13 - UIM / PCIM Wiring / Cables**

**Gen-1 Enumerated Vehicle CAN Signals**

| | | |
|---|---|---|
| 1) | Crash Event Status | a) No event b) Deploy event c) Fuel cutoff event |
| 2) | Driver Door Status | a) Closed b) Ajar |
| 3) | Hood Status | a) Closed b) Ajar |
| 4) | Passenger Door Status | a) Closed b) Ajar |
| 5) | Rear Left Door Status | a) Closed b) Ajar |
| 6) | Rear Right Door Status | a) Closed b) Ajar |
| 7) | Ignition Status | a) Off b) Accessory c) Run d) Start |
| 8) | A/C Request | a) Off b) On |
| 9) | Cruise Control Mode | a) Off b) Keeping speed c) Accelerating d) Decelerating e) Resuming high f) Resuming low g) Tap-up waiting h) Tap-down waiting |
| 10) | A/C Compressor Clutch | a) Off b) On |
| 11) | Door Lock Status | a) Double-locked b) All locked c) All unlocked d) Driver unlocked |
| 12) | Malfunction Indicator Light | a) Off b) On c) Flash |
| 13) | Oil Pressure Lamp | a) Off b) On |
| 14) | Driver Seat Belt | a) Faulty b) Belted c) Unbelted |
| 15) | Passenger Seat Buckle | a) Faulty b) Belted c) Unbelted |
| 16) | Restraints Indicator Lamp | a) Off b) On |
| 17) | Crash Event Severity | a) Normal b) Threshold 1 exceeded c) Threshold 2 exceeded |
| 18) | TPMS Status | a) TPMS system fault b) TPMS sensor fault c) Tire pressure low d) Tire pressure normal |
| 19) | Auto Trans Gear Status | Not Available |
| 20) | Engine Status | a) Off b) On c) Auto-stopped |

**Gen-1 Analog Vehicle CAN Signals**

| | | | |
|---|---|---|---|
| 1) | Vehicle Battery Voltage | > = < | _____ % |
| 2) | Odometer Reading | > = < | _____ km |
| 3) | Fuel Level | > = < | _____ % |
| 4) | Outside Air Temp | > = < | _____ °C |
| 5) | Engine Coolant Temp | > = < | _____ °C |
| 6) | Engine Speed | > = < | _____ RPM |
| 7) | Vehicle Speed | > = < | _____ kph |
| 8) | Transmission Oil Temp | > = < | _____ °C |

**Input Signals to UIM from Upfitter System**

| | |
|---|---|
| Upfitter Switches #1 – 9 | High / Low (configurable) |
| Upfitter Switch #10 | Low Only |

**Output Signals from UIM to Upfitter System**

| | |
|---|---|
| Switches #1 – 8 | High |
| Switches #9 – 15 | Low |

**Figure 14 – UIM Gen 1 Available Signals**

**Gen-2 Enumerated Vehicle CAN Signals (incremental to Gen-1)**

| | | |
|---|---|---|
| 1) | High Beams | a) Off b) On |
| 2) | Low Beam | a) Off b) On |
| 3) | Rear Fog Lamp | a) Off b) On |
| 4) | Front Fog Lamp | a) Off b) On |
| 5) | Stop Lamp | a) Off b) On |
| 6) | Right Turn Lamp | a) Off b) On |
| 7) | Left Turn Lamp | a) Off b) On |
| 8) | Hazard Lamps | a) Off b) On |
| 9) | Park Lamp Status | a) Off b) On |
| 10) | Headlamp Switch Position | a) Off b) Park c) Headlight d) Auto |
| 11) | Rear Barn / Tail-gate Ajar | a) Off b) On |
| 12) | Manual Trans Gear | a) Reverse b) Other |
| 13) | Brake Pedal Status | a) Off b) On |
| 14) | Parking Brake Status | a) Off b) On |
| 15) | Change Oil Lamp | a) Off b) On |
| 16) | Frost Warning Status | a) Off b) Amber c) Red |
| 17) | Vehicle Alarm | a) Inactive b) Active |
| 18) | Engine Re-crank | a) Not Supported b) Supported c) Shutdown in Progress d) Low Voltage Event e) Fault |
| 19) | RPM Speed Control Mode | a) Off b) 3-speed Mode c) Variable Mode d) Idle-up Mode e) Split-shaft Stationary |
| 20) | Trailer Status | a) Disconnected b) Connected |
| 21) | Trans Oil Temp Valid | a) Default b) Valid c) Missing d) Faulty |

**Gen-2 Analog Vehicle CAN Signals (incremental to Gen-1)**

| | | | | |
|---|---|---|---|---|
| 1) | DPF Regen Level | > = < | In-range, Out-of-Range | _____ % |
| 2) | Smart Regen Charging | > = < | In-range, Out-of-Range | _____ % |
| 3) | Vehicle Tilt Angle | > = < | In-range, Out-of-Range | _____ ° |
| 4) | Battery Temp | > = < | In-range, Out-of-Range | _____ °C |
| 5) | Battery Current | > = < | In-range, Out-of-Range | _____ amps |
| 6) | Clutch Pedal Status | > = < | In-range, Out-of-Range | _____ % |
| 7) | Accelerator Position | > = < | In-range, Out-of-Range | _____ % |

**Other Gen-2 Incremental Capabilities**

1) UIM Private CAN-bus 1 Hz output (to upfitter body).
2) Programmer (Project Editor) has 8 logic terms (A-H), was 3 (A-C) in Gen-1.
3) Added “In Range” and “Out of Range” options to Analog CAN Signals logic programming.
4) Can add a virtual logic row in the Project Editor file.
5) Debugger function added to Project Editor (in Tools).

**Input Signals to UIM from Upfitter System**

| | |
|---|---|
| Upfitter Switches #1 – 9 | High / Low (configurable) |
| Upfitter Switches #10 – 11 | Low Only |

**Output Signals from UIM to Upfitter System**

| | |
|---|---|
| Switches #1 – 8 | High |
| Switches #9 – 15 | Low |

**Figure 15 – UIM / PCIM Gen 2 Available Signals**

**Cooling System**

To achieve expected performance of the vehicle cooling system, the following recommendations should be heeded:

- Equipment such as lights, sirens, spare tires or any other accessories should not be installed in the grille area forward of the radiator or engine air inlet. Doing so restricts airflow through the radiator and engine compartments. See Figure 16 for illustrated examples.
- All Stripped Chassis and some Chassis Cab models have minimum Effective Front-End Opening (EFEO) areas that must be met. This information is provided in the program specific BBLBs.
- Do not alter, change the locations of, or remove the original equipment fan, fan clutch, or shroud.
- If engine coolant is added or replaced, the original coolant type must be used. The appropriate coolant specification can be found in the vehicle Owner's Manual, in the "Capacities and Specifications" section.
- Hoses which are added or replaced should be of the following type:
  - Radiator Hoses: EPDM Rubber reinforced with modified para-aramid fibers.
  - Heater Hoses – Supply Port: EPDM Rubber reinforced with meta-aramid or modified para-aramid fibers.
  - Heater Hoses - Return Port: EPDM Rubber reinforced with modified para-aramid fibers.
- All sections of hose with clearances less than 5 mm to adjacent components must have protective sleeve of Flexguard 2130 or Delfingen Langoflex PET-PA D.

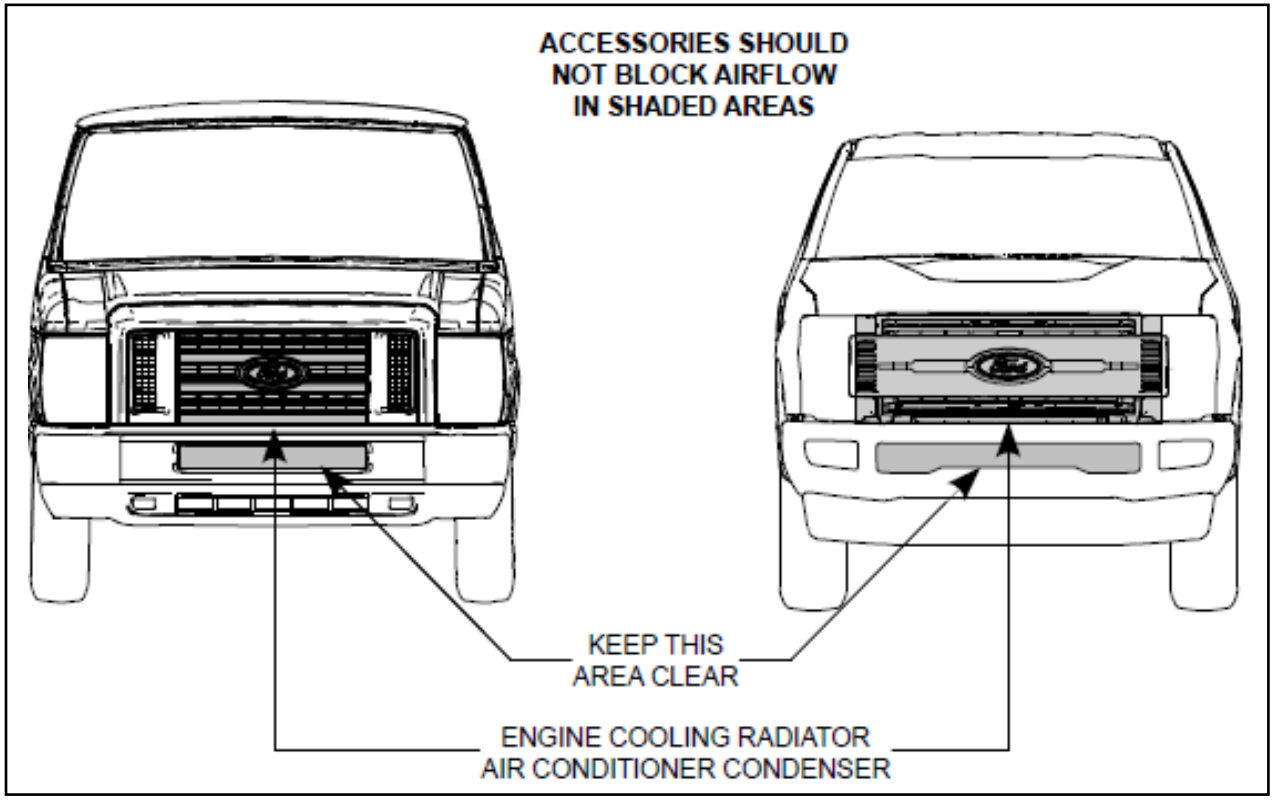


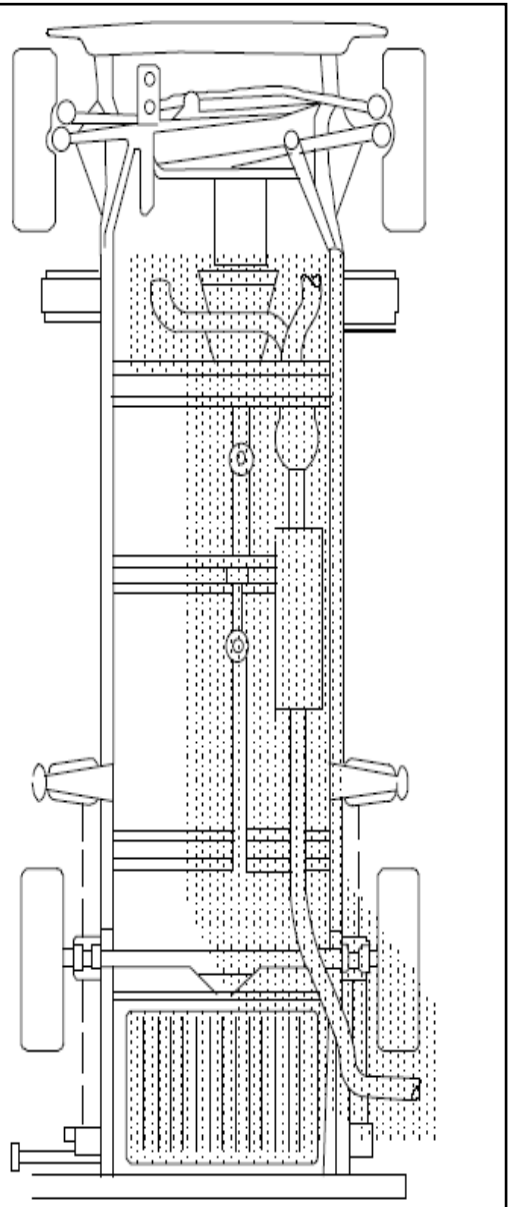

**Figure 16 – Examples of Areas Critical to Cooling**

- On Stripped Chassis models, the upper radiator hose must be retained to the fan shroud to avoid damage to the hose during vehicle operation. Otherwise, additional components should not be attached to the radiator or fan shroud.
- Revisions to the Front-End Accessory Drive System may affect the cooling system/component performance and are not recommended.
- Do not alter or modify the automatic transmission cooling system.
- Do not modify or remove any seals which are part of the cooling module (i.e., body seals, condenser seal, radiator seals, snow shield). These shields are intended to prevent engine heat recirculation.

**Climate Control System**

Some vehicles have an available Auxiliary Climate Control Prep Package that can be helpful in connecting auxiliary climate control systems to the Ford system. The following items are important for the maximum efficiency of the combined systems:

- A label stating the total refrigerant charge, type of refrigerant and type of compressor lubricant oil used must be affixed in a conspicuous place in the engine compartment.
- The A/C compressor will cycle during the defrost mode. A refrigerant shut-off valve for the auxiliary system may impair compressor lubrication.
- R-134a charged A/C systems should use barrier type A/C hose, SAE J3062 Hose Type $C_u$. Swaged, permanent fittings are recommended for this type of hose. Joint or connection types (serviceable fittings) should be Seal Washer, Dual Seal Washer, Seal Washer with O-ring, or Metal Seal Fitting (Metal Gasket) as shown in SAE J2727.
- Pursuant to California regulation 17 CCR §95663, the calculated leakage for applicable vehicle lines (as manufactured by Ford) is provided in the program specific BBLBs; look for "GHG Evaporative Emissions". If the vehicle air conditioning system is modified in any way, or air conditioning systems are added, the intermediate or final-stage manufacturer must calculate the final system leakage.



Bottom View Shown
Do Not Apply Undercoating to the Shaded Areas

**Figure 17 – Undercoating "Keep Out" Areas**

- When attaching an aftermarket AUX A/C unit to an existing OEM front A/C system, the AUX A/C unit must use a Thermal Expansion Valve (TXV). A Clutch Cycling Orifice Tube (CCOT) cannot be used.
- Compressor discharge gas temperature should never exceed 130°C [266°F] under any driving or idle conditions.
- Do not alter or change the pulley size.

Auxiliary heater and air conditioning system hose routings must consider the following:

- Dynamic engine roll or any system component which has an operating zone. Make sure there is adequate clearance to accommodate movement (e.g., transmission downshift linkage, steering column shift linkage).
- Do not route heater or A/C hoses directly over or near the exhaust system.
- Do not attach hoses to the engine.
- Use only metallic "Y" and "T" type fittings or OEM approved materials.
- Do not route hose in the wheelhouse area.
- Do not route hose by sharp edges or moving component parts. There must be shield protection from any potential abrasive source.
- When routing in stone kick-up area, lines should be protected by shields. Minimize the use of concentric protective heater hose shields. Limit length of concentric hose shields to 305 mm [12 in] maximum.
- Where possible, encase added suction lines in insulating foam from connector location under body to the secondary evaporator.

### Exhaust System

Warning: Vehicle Operating Temperatures: Some trucks manufactured by Ford Motor Company may exhibit high engine compartment and exhaust system temperatures in certain operating modes. Components, including exhaust heat shielding systems, have been installed as standard equipment on some vehicles to provide thermal protection against such temperatures. Aftermarket equipment installers, alterers, intermediate and final stage manufacturers SHOULD NOT REMOVE ANY COMPONENTS OR EXHAUST HEAT SHIELDING INSTALLED ON THE VEHICLE BY FORD MOTOR COMPANY and are responsible for providing thermal protection (e.g., under body heat shields) for any structure or equipment added to the vehicle.

To achieve expected exhaust system function, vehicle performance and effective heat management, the following recommendations should be heeded:

- Exhaust heat shields should be added to protect under body surfaces from heat radiated at any angle. Preferred method of attachment is banding, but welding is acceptable if it does not compromise the structural integrity or create a leak. Consider weld wire/band materials, they need to be equivalent to the OEM exhaust component material and compatible with the heat shield material.
- New exhaust pipe segments must include equivalent grass heat shields and top mounted heatshields as originally provided by Ford. These added shields must be of equivalent material and thickness. Depending on shield position, consider adding drain holes to prevent fluid retention.
- Do not apply body undercoating on the fuel tank, fuel fill hose, or fuel fill vent hoses. The extra insulation on these components may cause excessive heat build-up or possible material incompatibility concerns.
- Do not apply body undercoating within eight inches of any exhaust system component, or to any part of any exhaust system. See Figure 17. Undercoating may smoke or burn if subjected to high heat. See the "Heat Management" section for additional information.
- Do not substitute or remove exhaust system components furnished by Ford, except as noted in the program specific BBLB.
- For modifications to Diesel engine exhaust systems: The Maximum WOT Backpressure as measured at the end of the turbocharger outlet pipe must not exceed the value as produced by Ford under equivalent operating conditions.
- For modifications to Diesel engine exhaust systems: The maximum tail pipe outlet exhaust gas temperature versus time curve during the Diesel

Regen at Idle Cycle must not exceed the value as produced by Ford under equivalent operating conditions.

- For modifications to Gas engine exhaust systems: The Maximum WOT Backpressure as measured at the manifold outlets must not exceed the value as produced by Ford under equivalent operating conditions.
- Exhaust pipe extensions or added segments must be of equivalent diameter, gauge, and material as that originally provided by Ford. This will maintain proper corrosion protection and durability.
- If the exhaust system length is modified, incremental hangers/isolators should be considered, or existing hangers/isolators may need to be strengthened. Do not use rigid connections to the body. Consider thermal expansion of materials and the effect on static and dynamic clearances. Maintain ground clearance at the current production height.
- The minimum clearance between the exhaust system and surrounding critical components must maintain OEM clearances. Additional shielding may be needed for any modifications.
- Do not reuse the exhaust system clamps, fasteners, or gaskets. Replace them with new parts. Use Ford replacement parts or equivalent.
- If it is necessary to cut the exhaust pipe, use a saw or tube cutter, not a torch. Torch cutting leaves an uneven surface, which is a potential cause of exhaust leaks.
- Cut only on a horizontal straight segment of pipe.
- The tip of the exhaust outlet should protrude beyond the vertical surface of the Second Unit Body. If necessary, an extension should be added to the exhaust outlet pipe to direct exhaust away from the body and minimize the possibility of fumes entering the vehicle.
- If a Driver side exhaust outlet is desired, it is strongly encouraged to utilize the factory option where available. If relocated to the LH side of the vehicle, the exhaust pipe(s) must be routed carefully to avoid excessive heat transfer to fuel, vapor and brake system components and electrical wiring. The new exhaust outlet location should not be below the fuel fill location.

**Wheels and Tires**

WARNING: Use only replacement tires that are the same size, load index, speed rating and type (such as P-metric versus LT-metric or all season versus all-terrain) as those originally provided by Ford. The recommended tire and wheel size may be found on either the Safety Compliance Certification Label or the Tire Label which is located on the B-pillar or edge of the driver's door.

WARNING: Dual rear wheel vehicles may be shipped with the outer rear wheels removed. The dealer or alterer must ensure that the lug nuts are torqued to the proper specification before the vehicle is delivered to the final vehicle purchaser. Improperly tightened lug nuts could loosen and allow the wheel to come off while the vehicle is in motion, causing loss of control.

Use only wheels with the same load capacity, rim width, rim offset, and mounting configuration as those originally installed on the vehicle.

If the wheel lug nuts are loosened or removed for any reason, torque them to the specifications as listed in the applicable Owner Guide.

Tire Pressure Monitoring System (TPMS)

The Tire Pressure Monitoring System is subject to interference from the addition of metallic structures between the wheel-mounted sensor transmitters and the on-board receiver. Additionally, TPMS is subject to interference from any added equipment or device that emits radio frequency (RF) energy.

Even without interfering factors, the TPMS system has a maximum distance between the wheel sensors and receiver within which the system is robust. Do not extend the vehicle wheelbase beyond the longest factory offered variant with TPMS for the vehicle line in question, unless specifically mentioned in the IVM or program specific BBLB.

For Dual Rear Wheel Vehicles, it is important that the inside and outside wheel have valve stems positioned 180 degrees apart.

**Brake System**

WARNING: Do not wrap brake lines with any material that could cause water, dirt, sand or other foreign material to accumulate around the lines, potentially causing brake line damage or corrosion.

Guidelines for modification of hydraulic service brakes lines:

- Before and after cutting brake lines, drain, recover, clean up, and remove all the brake fluid, including drippings, from the area. Brake fluid is flammable. Discard all drained fluid appropriately.
- Remove the steel brake line from the frame clips. Avoid bending or crimpling the lines.
- Cut the brake lines on a straight segment parallel to the frame. Some brake lines have a hardened wire wrap for chafe protection. It is recommended that the wire wrap and the brake line be cut by grinding. Other industry cutting methods are acceptable if tubing integrity is maintained, and care is taken to prevent contaminants from entering the lines.
- All splicing of brake tubing must be done with steel tubing, threaded fittings, double flared joints, and brass unions of equivalent OEM quality. Use only SAE J526 or J527 steel tubing or equivalent.
- Do not kink or crack tubing when forming extensions of the existing tubing.
- Secure the brake lines to the frame with clips and clip spacing similar to that used with the original brake tubing.
- Inspect the modified brake lines for possible chafe or rattle conditions with the frame, fasteners, or other lines. Wire wrap tubing in the areas that may require additional protection.
- Do not reuse recovered brake fluid as it may contain contaminants. Always replace the fluid with new OEM equivalent brake fluid.
- Bleed the brake lines; check for leaks per the Ford shop manual. Verify the system operation and function.

Guidelines for modification of Parking Brake cable system:

- Remove the parking brake cables from areas of modification to avoid damage. These cables are particularly sensitive to heat.
- Measure and record the exact position of the parking brake cable side rail bracket relative to the forward edge of the rear spring front hanger bracket (see Figure 18). This dimension is critical to the reconnection procedure, as the bracket must be remounted in the original OEM position relative to the spring hanger bracket.
- If necessary, remove the parking brake cable bracket located on the frame side rail. Care should be taken when removing the bracket to maintain its integrity and shape if this component will be remounted.
- For wheelbase modifications, a new intermediate cable, modified in length consistent with the frame change, will be required.
- Any new brake cables must be of OEM quality or equivalent.
- If necessary, reinstall the parking brake bracket on the frame side rail in the same position relative to the front edge of the rear spring front hanger bracket.
- Parking brake cable brackets should be welded to the frame, avoiding welding in the corners and utilizing standard industry practices for maximum weld integrity.
- Parking brake cable bracket attachment to the frame must be able to withstand a tension load of 800 pounds, without any significant deflection. See Figure 19.
- After final welding, repaint the exposed portion of the frame.

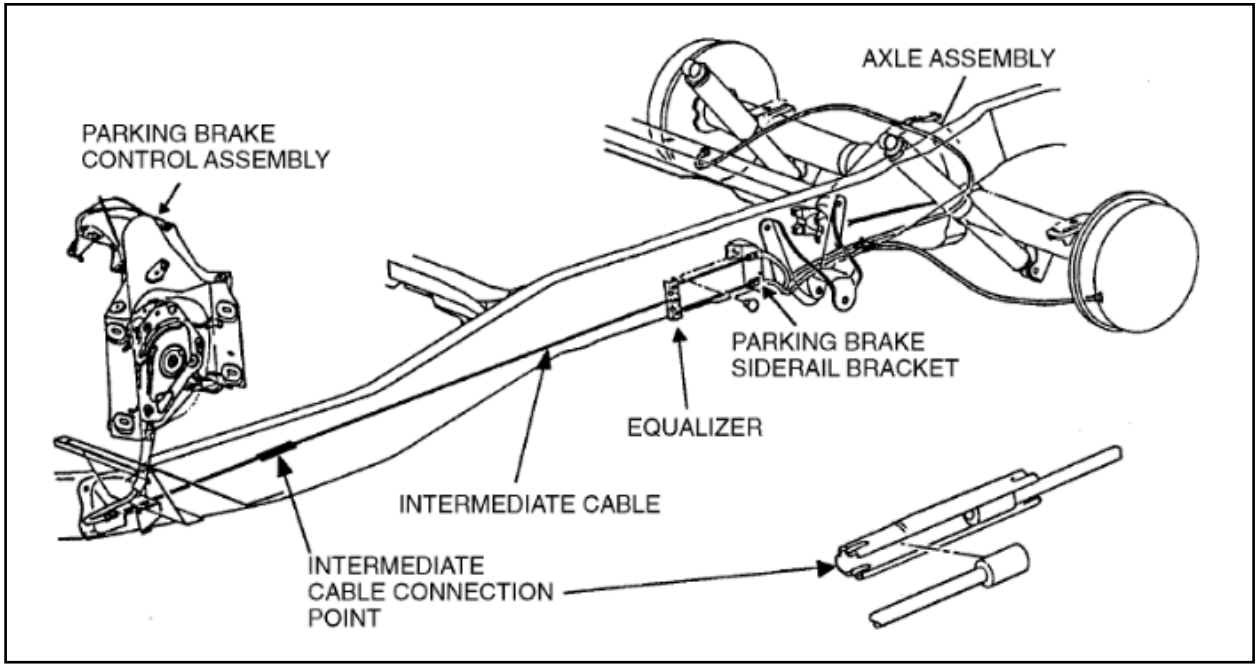



**Figure 18 – Example of Parking Brake Cable System**

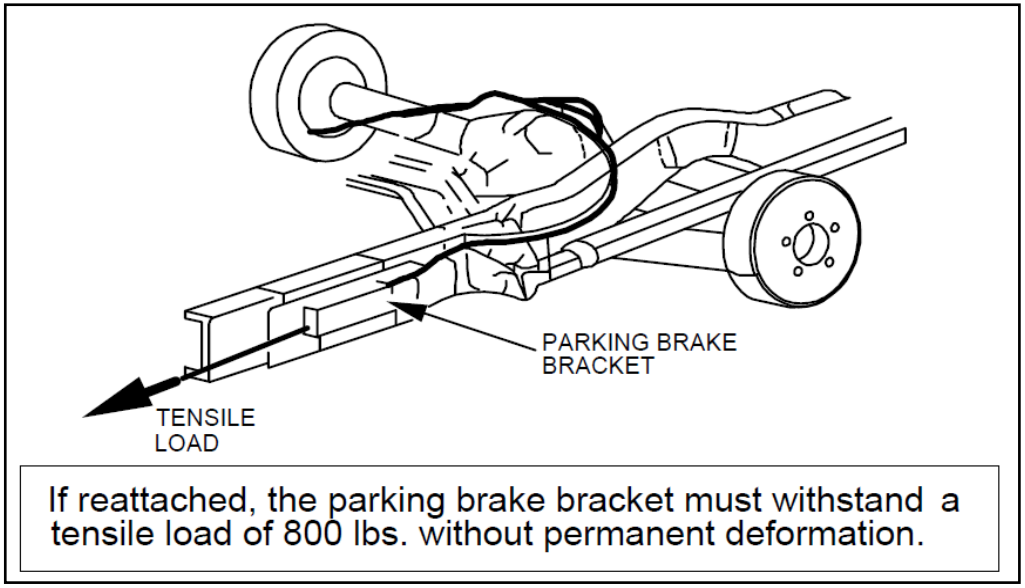

PARKING BRAKE
BRACKET
TENSILE
LOAD
If reattached, the parking brake bracket must withstand a tensile load of 800 lbs. without permanent deformation.

**Figure 19 – Parking Brake Bracket Strength**

**Suspension and Steering System**

IMPORTANT: The final-stage manufacturer is responsible for verifying that the front wheel alignment is within Ford specifications on completed vehicles. The steering wheel clear vision (horizontal or level orientation of the steering wheel) should also be maintained when resetting wheel alignment. These specifications are found in the “Suspension System - General Information” section of the Ford Shop Manual.

IMPORTANT: The steering gear, intermediate shaft, coupling shaft, linkage, column, and steering wheel should not be altered nor relocated. Steering linkage travel should not be restricted.

IMPORTANT: The weight of the body structure and its center of gravity location (both horizontally and vertically), as well as the weight and positioning of the cargo load, are important to the handling of the completed vehicle. Subsequent stage manufacturers should note that matching a body to a chassis in a manner appropriate for the intended use of the vehicle is the responsibility of the final stage manufacturer. Following the representations in the Incomplete Vehicle Manual, with respect to center of gravity locations and body weights for compliance with Federal or Canadian Motor Vehicle Safety Standards is only part of the task of producing a completed vehicle that handles appropriately in service.

IMPORTANT: Modifications made by subsequent stage manufacturers, particularly those that significantly affect vehicle ride heights or off-loading of vehicle weight from the front of the chassis (frame stretch, addition of a lift gate, etc.) may cause increased tire wear and/or vehicle control problems, possibly leading to rollover or other accidents that could result in death or serious injury.

NOTE: Front end alignment warranty policy for incomplete vehicles is based upon the completed vehicle remaining within OEM weight ratings, vehicle attitude, suspension and wheel/tire guidelines, and other characteristics affecting wheel alignment. Exceeding or modifying these restrictions may jeopardize related warranty.

The following recommendations should be followed:

- Front or rear suspension components should not be drilled, cut, welded, or relocated for any reason.
- Welding to the frame in proximity to the steering gear is not recommended.
- If rear suspension spacers are used between the spring and axle seats to accommodate side-to-side variations, they should not exceed 3/8 inch. The spacers should not exceed the profile of the axle spring seat. Additional spacing may adversely affect driveline angles and axle system package clearance. Also affected are spring stress limits from excessive jounce travel.
- Do not use any suspension component as a welding ground.
- When welding or cutting near suspension components, shield and protect all springs and rubber components from heat penetration and welding splatter.
- Any add-on device mounted on the steering column, shroud, multifunction switch, or gear selector lever, must not affect steering column angles, tilt mechanism (if so equipped), range of operation, or steering column mounting hardware. Any such device must not interfere with steering column collapse stroke travel during crash situations or air bag deployment.
- Vehicles equipped with an air suspension system must verify that the settings are correct once the vehicle is completed by the final stage manufacturer. The applicable settings and process are found in the “General Procedures” folder in the Rear Suspension Section of the Ford Shop Manual

**Engine**

The following recommendations should be heeded to ensure proper engine performance:

- The engine should not be operated with the hood up or removed. This may allow excessive unforced air to circulate, potentially having an adverse effect on the cooling system.
- Do not use manual throttle kickers.
- When using electronic throttle kickers on gasoline engines, set the high idle RPM at as low as possible to obtain the required performance. The idle speed must be set when the engine is at normal operating temperature and under normal load. This RPM setting should be affixed to the vehicle and should be checked after the 2,000-mile break-in engine tune up. The addition of throttle kickers may affect electronic transmission operation.
- An auxiliary crankshaft bearing support is required on all modular gas engines before a FEAD-mounted PTO can be installed.
- Do not tap into the electrical circuits attached to the Accelerator Pedal Position (APP) Sensor on the accelerator control. Do not bypass the electrical circuits attached to the APP.
- Installation of a gasoline engine speed governor is permissible, provided the governor design is compatible with each respective throttle body for the individual engine application and it does not exceed the specified engine maximum RPM. It must also meet all noise and engine emission requirements. Governor installations may affect electronically controlled transmissions. Contact the Ford Truck Body Builders Advisory Service before installing. Ford Motor Company also offers OEM production options for speed limiting on multiple vehicle lines, see vehicle Order Guides for additional information.

**Transmission**

The following recommendations should be heeded to ensure proper function of the transmission system:

- The transmission oil filler tube and dipstick must not be altered by bending, lengthening, or shortening, and must be readily accessible for checking lubricant level. NEVER ATTACH ANY COMPONENT TO THE TRANSMISSION FILLER AND DIPSTICK TUBE.
- The installed engine angle must not be altered. The relative position of engine and transmission to shift linkage must not be altered.
- Transmission vent must not be altered, pinched, or collapsed, and the vent opening must not be restricted or relocated.
- Adequate tool clearance and suitable access openings for transmission adjustments must be provided. Transmission removal provisions must also be considered.
- Transmission oil cooler lines should not be kinked, bent, or restricted. All oil cooler lines must be properly retained with adequate clips. The truck type external oil cooler must not be "boxed in", which would restrict adequate air circulation. Use only Ford factory coolers. Some automatic transmissions are equipped with "Stand Alone" transmissions fluid coolers. Vehicles equipped with oil-to-air cooler (OTA) may not have a transmission fluid cooler in the radiator.
- Transmission shift cable, transmission outer shift lever, and shift cable bracket must not be altered and must have provisions for adjusting tool clearance. A severe duty shift cable (booted) is available as a service part, from a Ford Dealer, for Super Duty F-Series vehicles which experience extensive off-road use.
- Some automatic transmissions may be equipped with a transmission cooler bypass system. The purpose of the cooler bypass valve is to allow some transmission fluid to bypass the transmission fluid coolers and return to the transmission sump during cold weather operation. This provides a faster transmission fluid warm up and increased lube flow during cold weather operation. Do not remove nor modify this system or transmission damage may occur. Do not use the cooler bypass line as a fitting point. Vehicles equipped with transmission cooler bypass will NOT have a hot water feed circuit from the water pump to the radiator tank containing the transmission cooler.
- Electronically controlled automatic transmission wire harness routing location, wire harness locating clips, all heat shielding, and clearance to the exhaust must be maintained as installed by Ford.

**Driveline**

The following recommendations should be heeded to ensure proper driveline performance:

- Rear axle vent and hose, if installed, must not be bent, pinched, or obstructed so that normal "breathing" of the rear axle is provided.
- On all rear axle assemblies, additional bracket bars or supports must not be welded to the axle assembly. Attachment of any equalizing-type trailer hitch or auxiliary suspension systems (springs) must not be attached to the rear axle assembly.

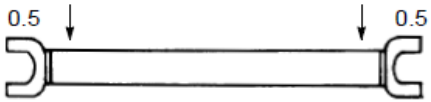
When removing a driveshaft, follow these recommendations:

- Match-mark the driveline attachment at the transmission or transfer case and rear axle before it is removed. This will assure identical reinstallation that is critical to driveline balance and phasing.
- If a driveshaft is modified, it should be rebalanced, and the new high spot mark should be compared to the previous.
- Retain and tape the bearing caps to the universal joints to assure needle bearing integrity.

Driveline Balance, Runout and Sizing

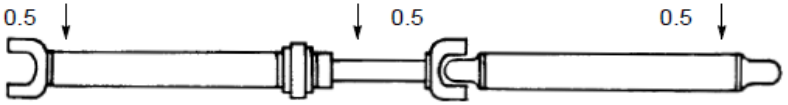
See Figure 20 for guidelines on Driveline balancing. In general, limit the amount of balance weight to approximately 3 ounces or less at each end of the shaft. If excessive weight is required for balance, it is likely that the shaft is distorted beyond the runout specifications and should not be used. Compare the shaft runout against the specifications listed below to determine if any given shaft is worth balancing.

A. INDIVIDUAL DRIVESHAFTS: Maximum imbalance of 0.5 ounce-inch at both ends.




B. MULTIPLE DRIVESHAFT SYSTEMS SHOULD BE SYSTEM-BALANCED

1. TWO-PIECE DRIVESHAFT SYSTEMS: Maximum imbalance of 0.5 ounce-inch at both ends of the system, and at the center of the system where the shafts are joined.




2. THREE-PIECE DRIVESHAFT SYSTEMS: System-balance two of the shafts as in "B", then assemble the third after it has been balanced individually as in "A".

C. Balancing of the driveshaft, or system, should be done at 3,000 rpm.

D. Balance weights should be placed within 3.0 inches from the ends of the driveshaft tube, and no closer than 1.0 inch from a weld.

**Figure 20 – Driveline Balancing Guidelines**

See Figure 21 for guidelines on runout limits for unbalanced drive shafts

See Figure 22 for guidelines on shaft diameters

Some drive shafts may have an internal damper which may need to be re-tuned if the driveshaft length is modified. The presence of an internal damper can be confirmed visually when the driveshaft is "open" for modification.

To meet minimum shaft quality requirements, the shaft should be made from cold-rolled steel, 0.083-inch minimum thickness. Weld seam to form a tube.

Driveline Angles

After the vehicle build is complete, the driveline angles must meet the following "rules", both at unloaded and fully-loaded vehicle attitudes.

1) The NET OPERATING ANGLE, at any individual joint, must be at least 0.5 degree, and not exceeding 3.0 degrees. The NET OPERATING ANGLE (Θ) is equal to the root sum of squares (RSS) of the side and plan view angles between two segments of the drivetrain (See Figure 23). Figure 24 illustrates a typical driveline system. Using this figure, the Net Operating Angle of each joint would be calculated as shown in Figure 25.

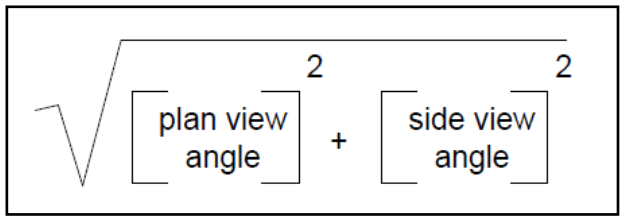



**Figure 23 – Net Operating Angle Equation**

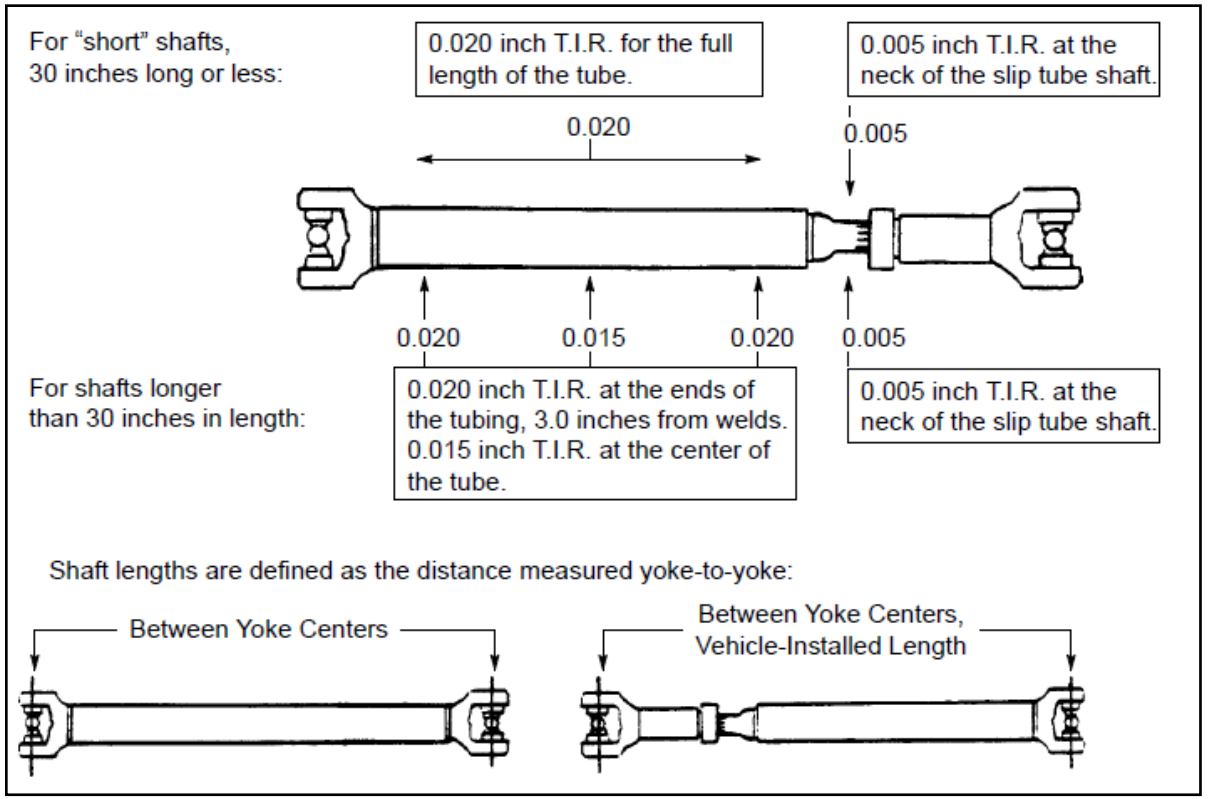

For "short" shafts, 30 inches long or less:
0.020 inch T.I.R. for the full length of the tube.
0.005 inch T.I.R. at the neck of the slip tube shaft.
0.020
0.005
0.020
0.015
0.020
0.005
For shafts longer than 30 inches in length:
0.020 inch T.I.R. at the ends of the tubing, 3.0 inches from welds. 0.015 inch T.I.R. at the center of the tube.
0.005 inch T.I.R. at the neck of the slip tube shaft.
Shaft lengths are defined as the distance measured yoke-to-yoke:
Between Yoke Centers
Between Yoke Centers, Vehicle-Installed Length

**Figure 21 – Driveline Runout Guidelines**

| If the shaft length is: | Then the minimum shaft diameter should be: |
|---|---|
| 0 to 51 inches long | > 3.0 inch |
| Up to 55 inches long | > 3.5 inch |
| Up to 59 inches long | > 4.0 inch |

**Figure 22 – Driveline Diameter Guidelines**

2) The combination of NET OPERATING ANGLES, throughout the whole driveline, must "cancel." It is preferred that the NET OPERATING ANGLES at either end of a shaft be within 1 degree of each other. At a minimum, the formulas in Figure 26 must be satisfied for sufficient "cancellation" to occur:

3) The center bearing mounting bracket, surrounding the rubber insulator, must be 90 +/- 3 degree to the center bearing. In other words, no more than 3 degrees of misalignment can be absorbed by the rubber surrounding the center bearing. See Figure 28.

Driveline Component Phasing: Ensure that u-joints are in-line to within +/- 2 degrees, See Figure 27. Ensure matching alignment arrows between slip yoke and tube shaft. Observe alignment arrows stamped on parts. If there are no alignment marks, add them before disassembly to ensure proper phasing alignment of shaft and yoke. See Figure 29.

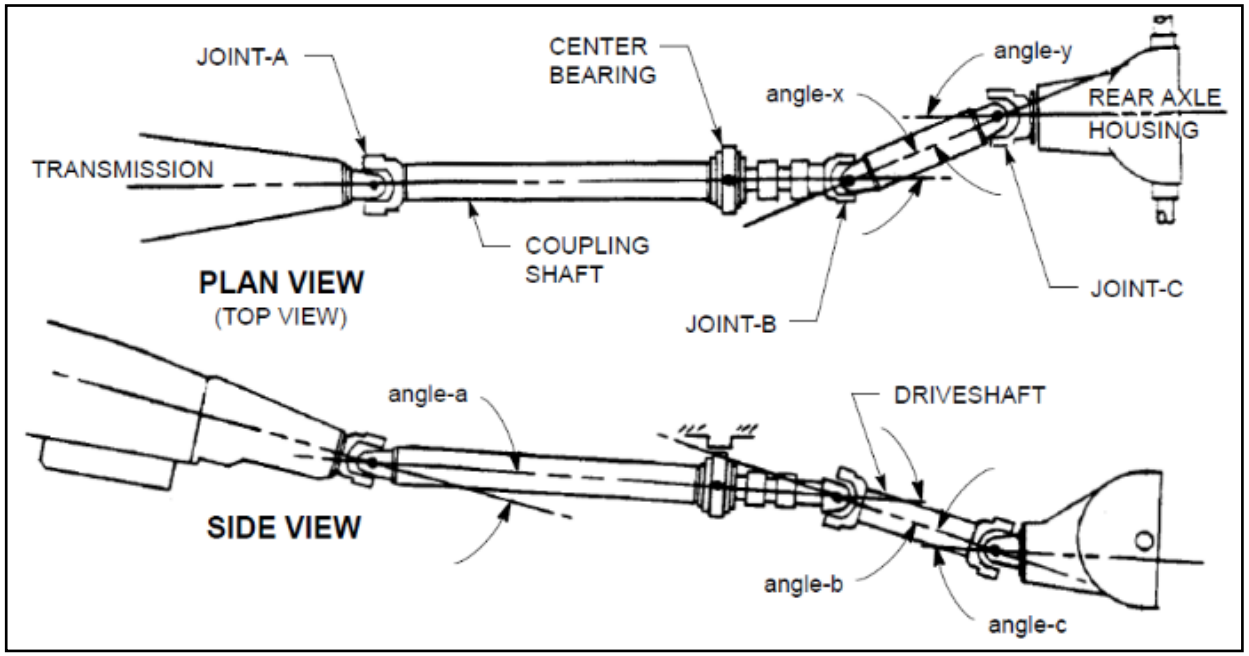



**Figure 24 – Example Driveline System**

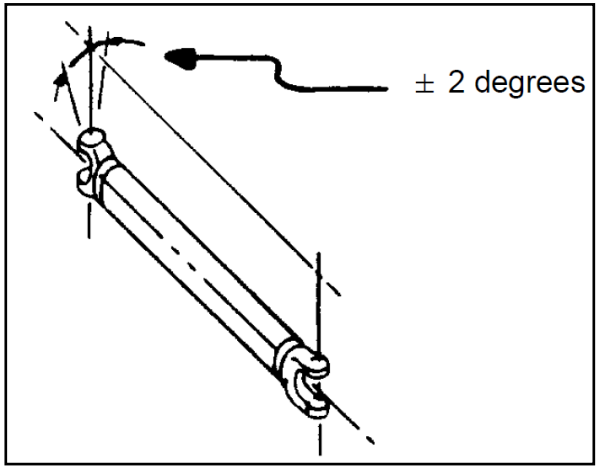



**Figure 27 – Driveline U Joint Alignment**

The NET OPERATING ANGLE at JOINT A = (Θa) = $\sqrt{[0]^2 + [\text{angle-a}]^2}$ ≥ 0.5° ≤ 3.0°

The NET OPERATING ANGLE at JOINT-B = (Θb) = $\sqrt{[\text{angle-x}]^2 + [\text{angle-b}]^2}$ ≥ 0.5° ≤ 3.0°

The NET OPERATING ANGLE at JOINT-C = (Θc) = $\sqrt{[\text{angle-y}]^2 + [\text{angle-c}]^2}$ ≥ 0.5° ≤ 3.0°

**Figure 25 – Example Net Operating Angle Calculation**

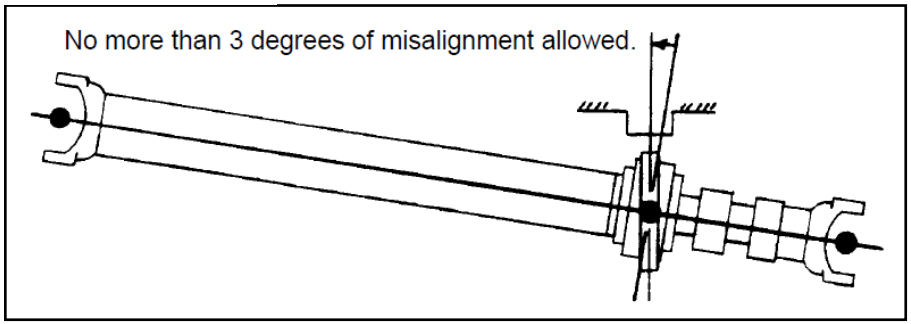



**Figure 28 – Center Bearing Alignment**

For a 1-shaft driveline: (2-joint) $\sqrt{\Theta a^2 - \Theta b^2}$ ≤ 3.0

For a 2-shaft driveline: (3-joint) (as exemplified in Figure 1) $\sqrt{\Theta a^2 - \Theta b^2 + \Theta c^2}$ ≤ 3.0

For a 3-shaft driveline: (4-joint) $\sqrt{\Theta a^2 - \Theta b^2 + \Theta c^2 - \Theta d^2}$ ≤ 3.0

**Figure 26 – Net Operating Angle Minimum Cancellation**

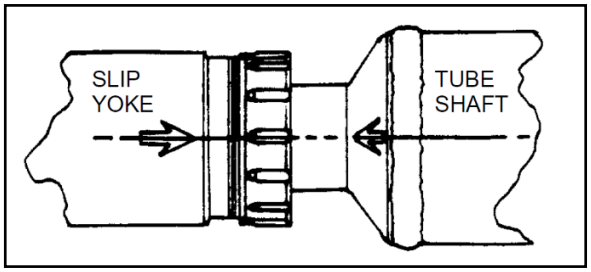



**Figure 29 – Component Alignment Markings**

**Frame**

WARNING: Failure to follow the recommendations below may weaken the vehicle frame, which could result in death or serious injury.

WARNING: When welding is performed anywhere on the vehicle, precautionary measures should be taken to prevent damage to electrical system wiring or components.

WARNING: The stability control system (if equipped) is specifically calibrated and validated only for the vehicle's original configuration. Significant vehicle alterations such as wheelbase extensions or reductions will affect the performance of the stability control system and may require updates to module configurations.

The following recommendations should be heeded to maintain proper function and performance of the vehicle frame:

- Use existing holes in the frame whenever possible.
- Holes are not to be drilled in the top or bottom flange of the frame side member, or in locations on the vertical frame side that would weaken the frame.
- Holes to mount brackets, out-riggers, and supports, may be drilled in the vertical frame side rail web with the following restrictions:
  - There must be a minimum of 1.5 inches of material between edge of hole and inside of upper or lower flange.
  - The minimum edge distance between any two holes up to 0.625-inch diameter must be 1.00 inch. For holes larger than 0.625-inch diameter, the minimum edge distance must be 1.5 times the diameter of the largest hole.
  - The maximum hole diameter for any hole in the frame is 0.75 inches.
  - Avoid drilling holes within 0.5 inch from the edge of any existing or added reinforcement.
- Avoid close vertical succession of fasteners (3 holes max).
- Adding holes or welding on frame cross members is not recommended.
- All attaching fasteners, including flat washers, must be of high strength steel (Grade 8 for SAE fasteners, Property Class 10.9 for metric bolts, PC 10 for metric nuts).
- Prior to welding, any parts which could be damaged by excessive temperatures should be removed or adequately shielded. Also, prior to welding, disconnect all batteries, and sensitive electronic modules (PCM, BCM etc.).
- Ensure the welder ground return clamp is positioned as close to the affected welding area as possible (not more than 12 inches). The welder ground return clamp should be on the same sheet metal or frame being welded upon. Welding cables should never be allowed to lay on, near, or across any electrical wiring or electronic component during welding. After welding, when parts are cool, carefully inspect wiring and electrical components for shorts or other damage which could draw excessive currents and possibly cause an electrical system short when the battery is reconnected.
- Do not weld on frame flanges, including the bend radii.
- When welding steel side rails, emphasis should be placed upon weld application techniques to avoid stress risers that may adversely affect frame operating stresses.
- When welding within 4 inches of any cross member or suspension rivets, remove the rivets and replace with appropriate threaded fasteners (Grade 8 for SAE fasteners, Property Class 10.9 for metric bolts, PC 10 for metric nuts). When welding within 4 inches of any bolted on cross member or suspension component, re-torque the fastener to the OEM torque specification.
- Do not modify or alter the convoluted frame sections in the area behind the front bumper. Modifications or alterations could have an adverse effect on vehicle performance in a crash situation.
- Recommend the use of OEM front tow hooks only. See the Owner's Manual for towing instructions.
- When U-bolts are used for the attachment of bodies to the truck chassis, vertical spacer bars must be used between the upper and lower flanges at each U-bolt to prevent collapse of the frame side rail flanges.

Wheelbase Modifications

The following section is oriented toward adding frame length to increase a vehicle wheelbase, the same process and procedures can be applied to shortening a vehicle wheelbase as well.

Frame splices are often made too rigid. Good frame splice design will allow the frame to flex and twist along its entire length. It is recommended that the frame splice technique described here be adopted to retain splice joint integrity. The critical aspects of frame splicing are cut location, alignment, and fit. A flat level work area is recommended. Jack stands should be properly located to stabilize the vehicle during the cutting operation. All the tires should be blocked front and rear.

Carefully chose a location to cut and extend (or shorten) the frame based on the following criteria:

- Minimize exhaust, fuel, brake, and electrical modifications.
- Minimize driveline modification issues concerning excessive drive angles and misalignment (see Driveline section of this document for more information)
- Maintain frame strength and integrity.
- Achieve minimum weld spacing from the spring hanger bracket, preventing rivet hole deformation.

Once a location has been chosen, follow these recommended steps:

- Disconnect the battery negative cable(s) and the PCM, BCM and other sensitive electronic modules.
- Most Ford OEM frames are e-coated for improved corrosion protection. This paint must be ground off locally before the welding operation begins.
- The cut location must account for the outer reinforcement, which will be added in a later operation. The reinforcement should extend beyond the frame by a minimum of 6 inches on either end.
- Scribe or mark the frame for cutting (See Figure 30). All dimensions for gauging or fixturing should be recorded at this time.
- Attach a cutting fixture to the frame for increased cut accuracy

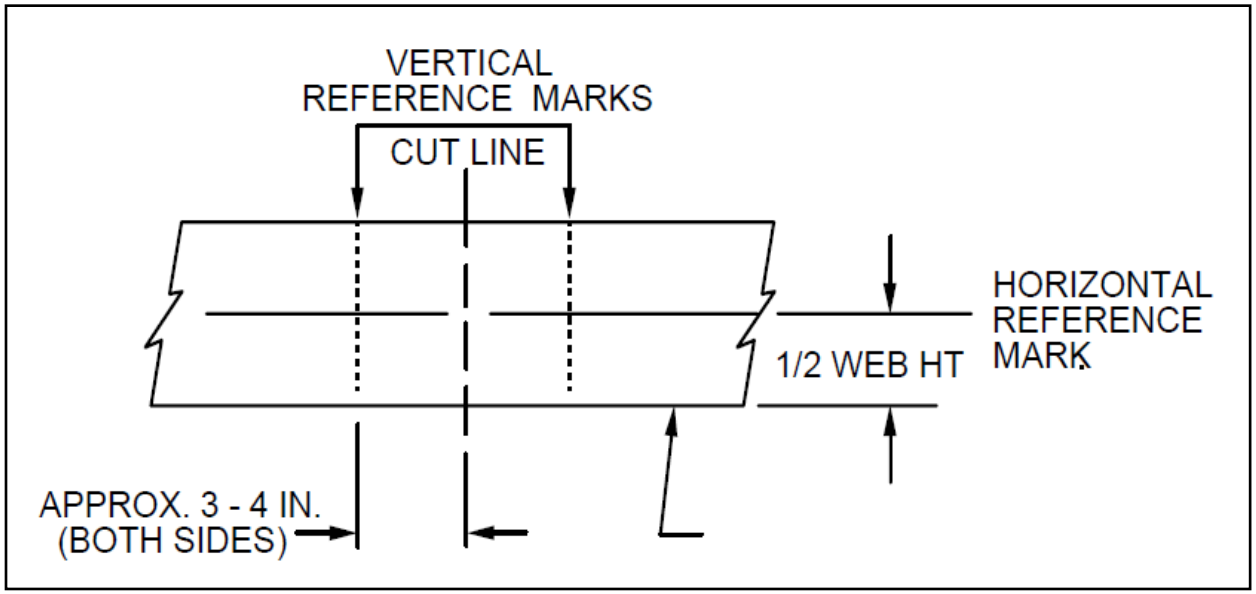



**Figure 30 – Horizontal and Vertical Reference Marks**

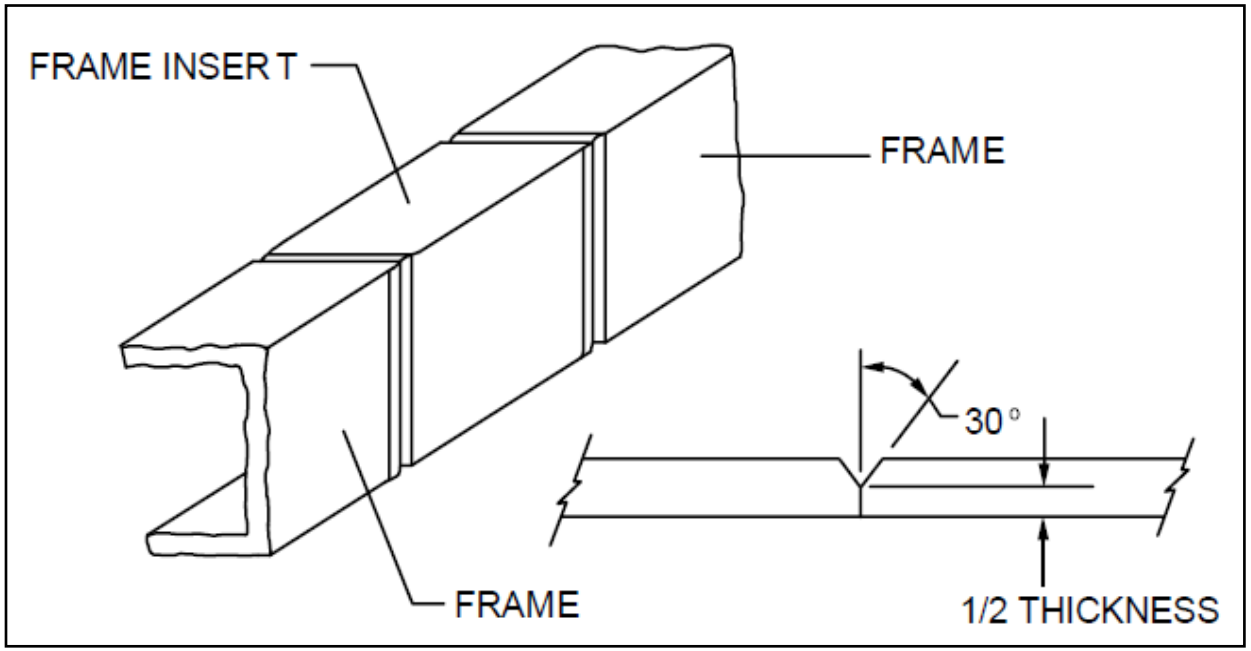



**Figure 31 – Chamfered Frame Rails Prior to Welding**

- Grind the cut edges of the frame smooth for a line on line fit. This will ensure a good and a clean metal surface for the welding operation.
- Frame inserts must be the same dimensional shape, gauge, material, and yield strength as the original side members. Frame material and yield strength can be found on the Ford BBAS site (select "Publications", then expand "Vehicle Specifications" and select the applicable vehicle line.
- Chamfer the outside edges of both the frame cut and the insert ends at a 30° angle, leaving half of the thickness. (See Figure 31)
- Move the rear frame section of the vehicle in order to allow placement of the frame insert.
- Fixture and clamp the insert to ensure correct alignment. Dimensional checks to the predetermined reference marks should be used to prevent any possible error. (See Figure 32)
- Tack weld run-off blocks to the edge of the upper and lower flanges of the frame and frame insert (See Figures 33 and 34). This procedure is recommended to eliminate joint edge burnout and to prevent movement during the butt weld procedure.
- Butt weld the ends of the frame insert to the frame. Butt welds on the outside surface of the frame should be done with a single pass, vertical, up. (See Figure 33)
- Butt weld the inside of the joint with a single pass, vertical, up. (See Figure 34)
- Visually inspect all the welds for defects. Maintain high quality welds, as they are critical to joint integrity.
- Remove the run-off blocks and chip or grind the joint smooth. Grind marks are to be parallel to the length of the frame. The finished joint should be the same thickness as the side member.
  Note: The outside surface of the frame weldment must be as smooth as the rest of the frame to provide for a flush fit of the reinforcement.
- The splice location and the length of the insert define the outer reinforcement length with a minimum 6-inch overlap on each end. This reinforcement is not to encroach on the rear leaf spring front hanger bracket. Welding within 4 inches of this area could shrink the spring bracket rivets, causing a loose joint. The reinforcement should have an L-shaped cross

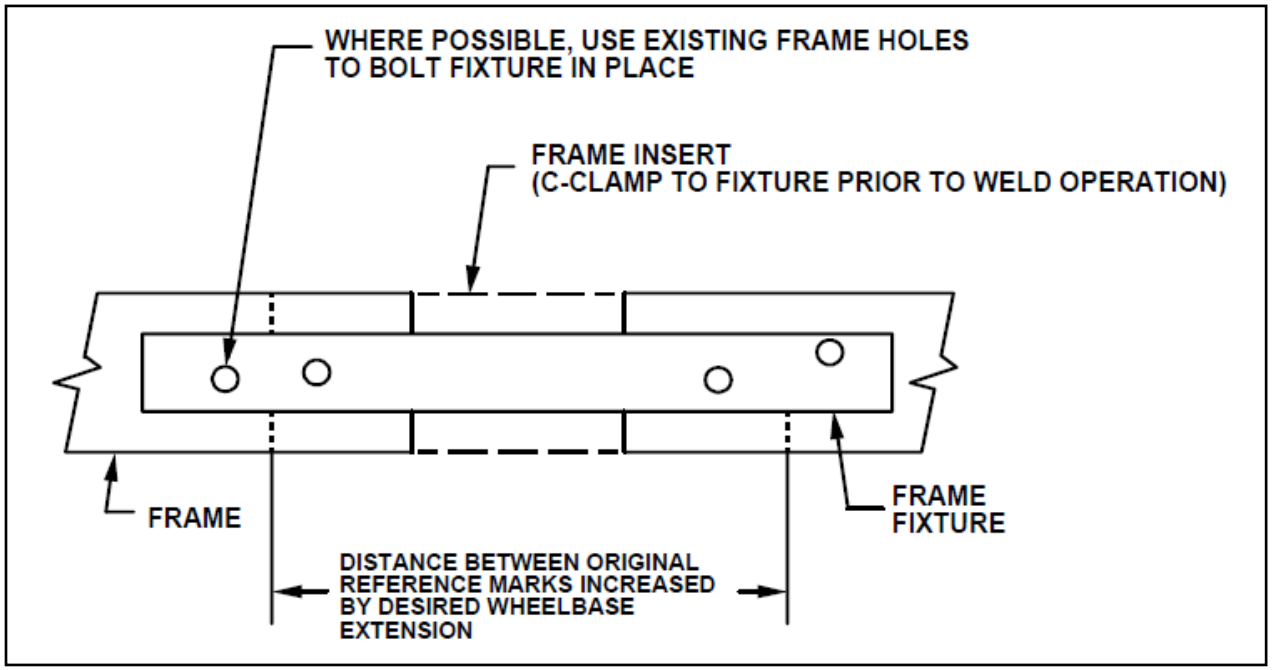

WHERE POSSIBLE, USE EXISTING FRAME HOLES TO BOLT FIXTURE IN PLACE
FRAME INSERT (C-CLAMP TO FIXTURE PRIOR TO WELD OPERATION)
FRAME
FRAME FIXTURE
DISTANCE BETWEEN ORIGINAL REFERENCE MARKS INCREASED BY DESIRED WHEELBASE EXTENSION

**Figure 32 – Welding Fixture**

section and be of the same material and thickness as the frame. The reinforcement height must allow for the weldment and not extend above the tangent of the radius for the band at the upper flange of the frame. (See Figures 35 and 36) Note: The reinforcement height must also allow for frame rail formations, if applicable, in order to provide a flush fit. The width should not exceed the lower flange width.

- Reinforcement slots or holes must be added to provide extra welding surface area for increased strength.
- The inside reinforcement bend radius must be larger than the outside radius of the frame to provide a gap at the bend. Refer to Figures 35 and 36 for greater detail. Add clearance holes to the reinforcement for all rivets, fasteners, or retention clips in the frame side member.
- Clamp the L-section reinforcement to the outside of the frame rail. There should be no visible gaps between the frame rail and the reinforcement other than at the bend. Fillet weld the reinforcement to the frame rail by using a skip weld technique. (A 2-inch weld followed by a 2-inch space continuous along the reinforcement – See Figures 35 and 36.)
- Leave the corners, bends, and radii "free" to flex. Welding in these locations can create stress risers that often lead to weld cracking.
- Do not weld the lower flange of the frame, neither on the flange nor at the edge.
- For the final weld operation, fillet weld the reinforcement slots or holes to the frame as shown in Figures 35 and 36. Although perfectly acceptable, it is not necessary to fillet weld the entire circumference of the slots or holes. Performing a fillet weld only on the bottom half (for 180º) will provide sufficient strength.
- After final welding, re-paint the exposed portion of the frame. Apply this re-painting step after all alterations and weldments on the vehicle are complete.
- Duplicate any frame identification number or VIN lost to the stretching or shortening of the wheelbase on the reinforcement or side member of the finished frame.

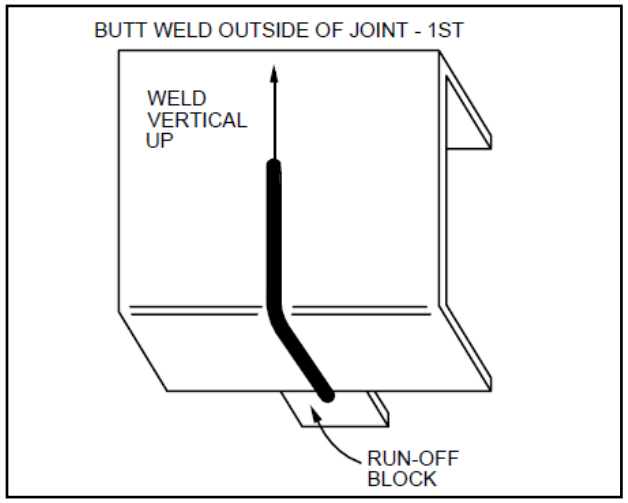



**Figure 33 – Welding Outside of Frame**

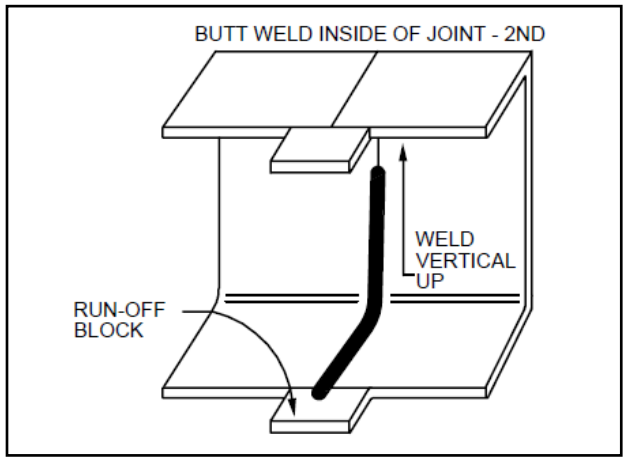



**Figure 34 – Welding Inside of Frame**

Note: Although Figure 36 ("Minimum Required Method") is acceptable, the method illustrated by Figure 35 ("Preferred Method") is preferred for the reinforcement fabrication and weldment for the following reasons:

- The slots are smaller and can be positioned to avoid clearance holes in the frame more easily.
- The chamfered sides diminish stress concentrations in corners reducing the chance of weld crack propagation.

Aft of Axle Frame Extension

Caution should be taken when extending the rear frame to avoid adversely affecting vehicle performance in the following areas:

- Excessive rear frame extension may cause a customer to significantly unload the front end of the vehicle. This could result in customer dissatisfaction with vehicle braking or steering and handling.
- Rear frame extensions need to be long enough to protect vulnerable components such as fuel tanks, and short enough to avoid frame contact with the ground when the vehicle is fully loaded. Refer to the "Ground Clearance" section for greater detail.

Frame extensions should have the same characteristics and be welded to the frame in the same manner as a “frame insert”, described in the prior section on “Wheelbase Modification”

If the vehicle has the potential for additional rear loading, such as that resulting from trailer towing, a rear extension reinforcement should be added, refer to Figure 37 and adhere to the following specification:

- Material: Same as frame rails. Frame material and yield strength can be found on the Ford BBAS site (select “Publications”, then expand “Vehicle Specifications” and select the applicable vehicle line.
- Size: Height = 4 inches (minimum) Note: The height may vary depending on the frame web height. It should not exceed the tangent to the radii at both the upper and lower flanges.
- Length = 12 inches
- Thickness = ¼ inch

All rear reinforcement plates should be skip welded around the perimeter in the same manner as a frame reinforcement, described in the prior section on “Wheelbase Modification”. In addition, the interior of the reinforcement should be attached in one of the following ways:

- A - Two 1½-inch diameter holes fillet welded to the frame/extension.

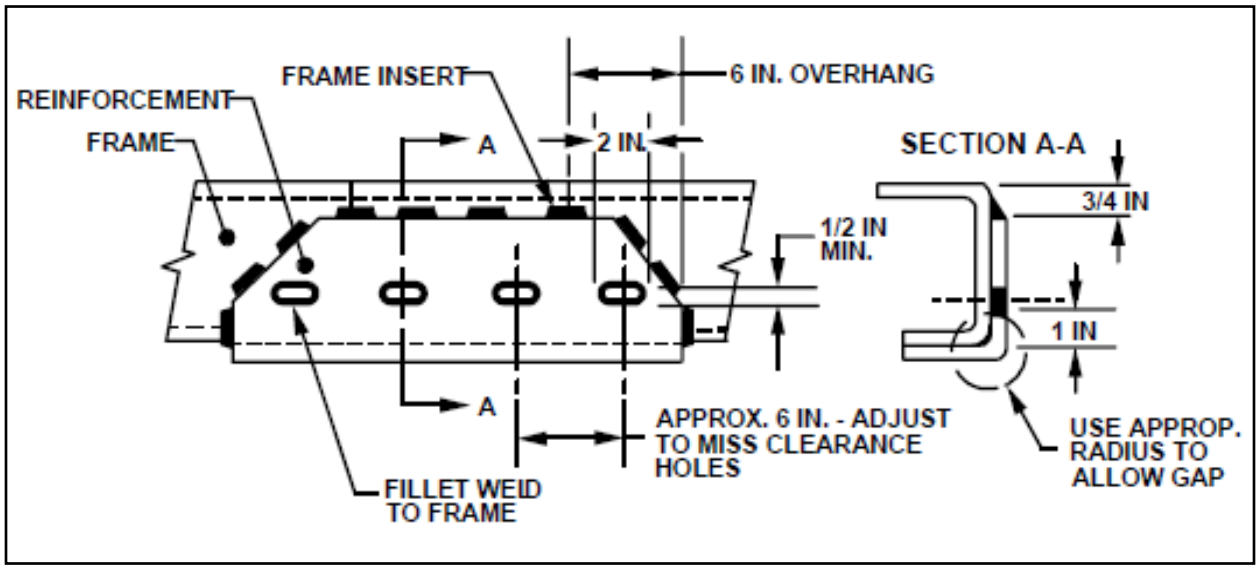



**Figure 35 – Preferred Method for Reinforcement and Welding**

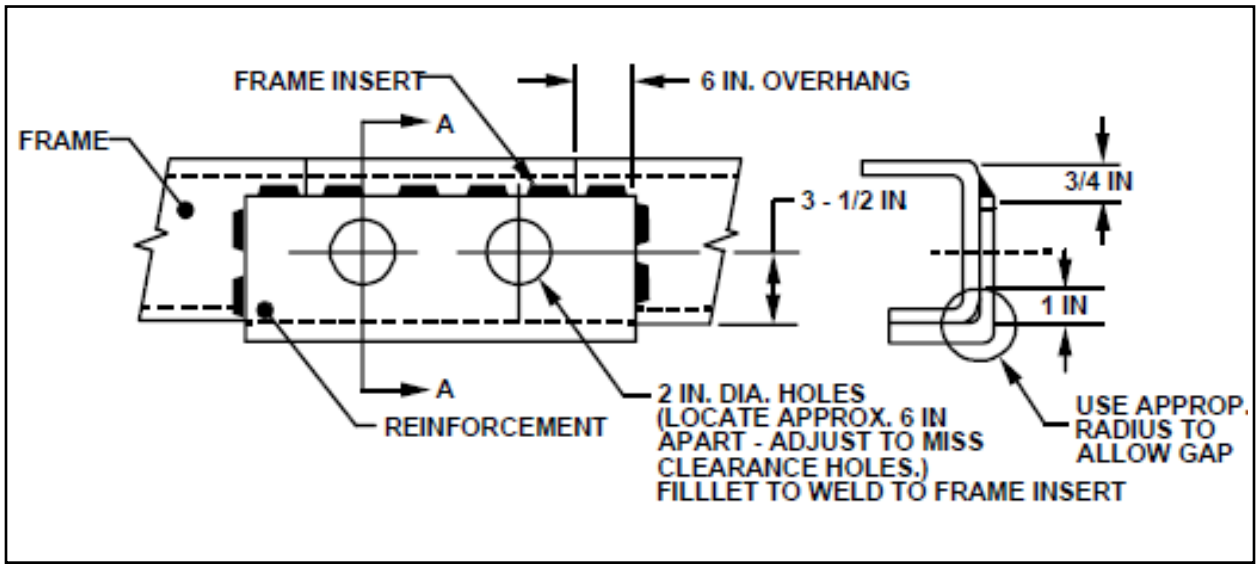



**Figure 36 – Minimum Required Method for Reinforcement and Welding**

- B - Four 7/16” or M12 fasteners (Grade 8 for SAE, PC10.9 bolts, PC 10 nuts for metric).

To maintain frame structural integrity, it is strongly recommended that an additional cross member be added to all rear overhang extensions extending 36-inches or more beyond the last OEM cross member.

If it is anticipated that a trailer hitch will be installed on the frame extension, the integrity of the extension and hitch combination should be verified.

If large diameter holes are to be added to the top flange of the rear extension (e.g. for mounting body isolators), a ⅞-inch hole spacing from the outside edge of the frame web and inside edge of the frame must be maintained. This will help to avoid stress cracks in the frame web and upper flange regions.

After final welding, re-paint the exposed portion of the frame.

Ground Clearance

The following will be used to evaluate body builder designs of the rear overhangs relative to ground clearance.

Definition: Angle of Departure - An angle between the ground line and a line formed by points A and B, as shown in Figure 38. It is measured with the vehicle loaded simultaneously to both the front and rear GAWRs. Point A is tangent to the tire Static Loaded Radius (SLR) (SLR values are provided in the program BBLBs). Point B is any point on the vehicle rearward of the rearmost laden tire. The "Primary Departure Angle" defines ground clearance.

Definition: Vulnerable Components - Any part of the vehicle system which is likely to be damaged if the vehicle contacts the ground and, as a result, adversely affects the operation of the vehicle. Ford recommends that a spare tire (if equipped) be considered a vulnerable component, in particular the tire sidewalls, which are more susceptible to damage.

Follow these guidelines when considering ground clearance:

- Vulnerable components should remain within a "protected area" defined as a minimum of 1.25-inches (30 mm) above the Primary Departure Angle (PDA) and no less than 8.25-inches (210 mm) above the ground.
- The PDA will use the end of the frame or rear bumper as Point B. Skid bars may not be used to redefine the PDA. However, a trailer hitch may be used to redefine the PDA under the following conditions:
  - Only Class II, III, or IV hitches can be used to redefine the PDA.
  - The only component of the hitch assembly that may be used to redefine the PDA is a metal hitch mounting cross member that extends the full width of the chassis frame. The hitch mounting brackets and the ball or tube receiver may not be used to redefine the PDA.
  - The trailer hitch assembly must be welded to the chassis frame. If it is otherwise fastened, the trailer hitch cannot be used to redefine the PDA.
- Any "easily removable part", such as a rear entrance step, may extend below the Primary Departure Angle, but should not create a secondary departure angle of less than 9º.
- The exhaust system can extend outside the PDA provided the system is free to lift clear of the departure angle.

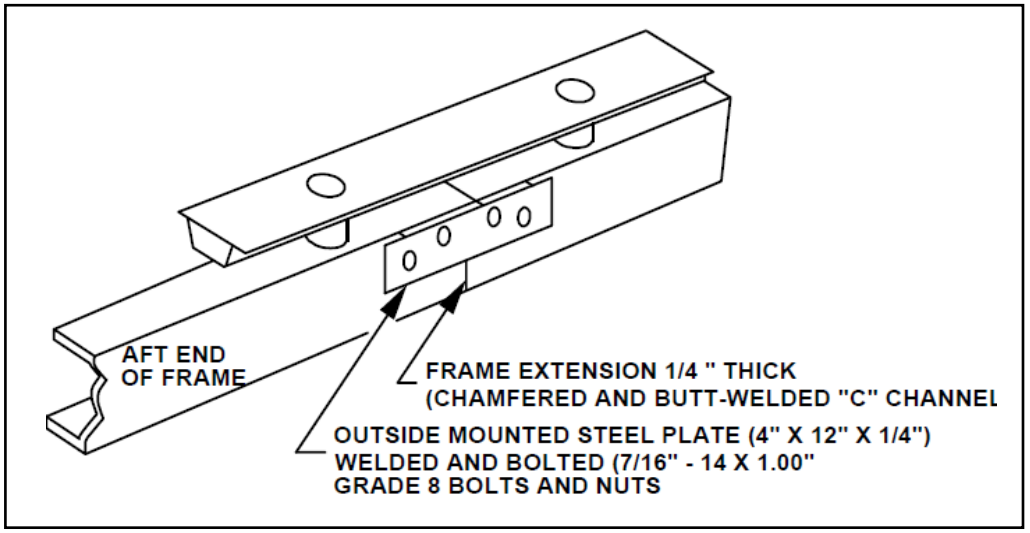

AFT END
OF FRAME
FRAME EXTENSION 1/4 " THICK
(CHAMFERED AND BUTT-WELDED "C" CHANNEL
OUTSIDE MOUNTED STEEL PLATE (4" X 12" X 1/4")
WELDED AND BOLTED (7/16" - 14 X 1.00"
GRADE 8 BOLTS AND NUTS

**Figure 37 – Rear Frame Extension Reinforcement**

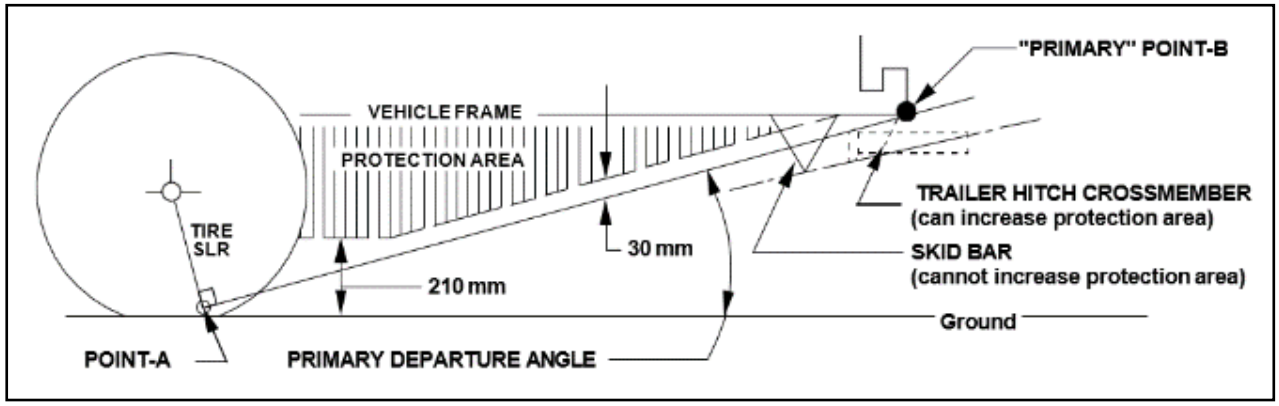



**Figure 38 – Departure Angle Definition**

**Occupant Protection Systems**

Ford Motor Company cautions subsequent stage manufacturers to note the definition of "Designated Seating Positions" in the Definitions section of this document. If a position can reasonably be used by a 5th percentile adult female for seating and the overall seat configuration and vehicle design make it likely that the position will be used by an occupant while the vehicle is in motion, then the position must be considered to be a "Designated Seating Position" for determination of compliance to U.S. and Canadian Motor Vehicle Safety Standards. Seat and seat belt systems may take many forms; this list of recommendations cannot cover all possibilities.

Seat Systems

WARNING: Ford Motor Company safety belts are designed to work with the seats originally developed for the vehicle. If a modifier uses different seats with Ford Motor Company seat belts, that modifier must ensure the safety belts and replacement seats meet all FMVSS requirements and will perform safely in the field. Failure to do so could result in serious injury in the event of a collision.

Any additional seats and seat anchorages installed by subsequent stage manufacturers must meet F/CMVSS 207 requirements and specifications.

The following recommendations should be heeded to ensure proper function of the vehicle seating systems:

- Do not modify or alter Ford Motor Company furnished seating or occupant restraint system. When utilizing the Ford Motor Company driver's seat delete package, care must be taken to insure proper function of the seat adjustment latching mechanism, electrical wiring and seat belt buckle pre-tensioner.
- If the seat or seat belt components are temporarily removed for any reason, they must be re-installed IN THE SAME VEHICLE in accordance with the instructions and specifications found in the applicable Ford Shop Manual.
- Seating systems that include the attachment of lap belt or shoulder belt assemblies should also consider the requirements of F/CMVSS 210 as part of the seating system.
- Seating system components should be free of sharp edges to prevent damage to seat belt systems when the belts could potentially contact the seating system components.
- Seats should be mounted with appropriate fasteners in the mounting holes provided, since these holes are located to utilize floor pan structural reinforcements.
- If additional holes are required in the floor for any reason, their locations should be carefully selected so that the structural integrity of the floor pan will not be compromised and damage to other components located below the floor will be prevented.
- Seating systems should be designed to be compatible with the seat belt systems, to permit proper adjustment, allow for occupant movement and provide convenient accessibility of the restraint system buckle release.
- Seats not designated for occupancy while the vehicle is in motion must be conspicuously labeled as such.
- Any additional seats, flip/folding seats or otherwise modified seats must not interfere with the design performance of installed side curtain or seat side airbags.
- If seats are removed during the upfit process, care must be taken to:
  - Not damage wiring/connectors when unclipping/removing from seat frame.
  - Avoid debris from entering the seat belt buckle system.
  - Avoid damage of wiring/sensors located under the seat frame (including properly routing and clipping as received to avoid pinched wires).
  - Cover and protect any unconnected connectors (located on seat pedestals).
  - Carefully reconnect all electrical connectors, ensuring that they are fully seated.
  - Perform any testing procedures recommended in the service manual.

Lap and Shoulder Belt Systems

WARNING: The seat belt buckle pre-tensioners, air bags and electronic sensor module are barcoded with a unique serial number which is matched to the vehicle VIN. To maintain the occupant protection system performance, the completed vehicle must contain the same seat belt buckle pre-tensioner, air bags and electronic sensor module that were installed by Ford Motor Company. Failure to do so could result in serious injury in the event of a collision.

The following recommendations should be heeded to ensure proper function of the Lap and Shoulder Belt System:

- The front seats are equipped with a pyrotechnic buckle pre-tensioner. The buckle pre-tensioner reduces slack in the lap and shoulder safety belt by pulling the buckle downward. The buckle pre-tensioners and air bags operate on the same sensors and will function simultaneously.
- Additional lap and shoulder belt assemblies, including retractors and hardware, must comply with the requirements of F/CMVSS 208 and 209.3.
- Additional lap and shoulder belt system anchorages must comply with the requirements of F/CMVSS 210.
- Lap and shoulder belt systems that are attached to the seat frame or base may affect compliance of the seating system with the requirements of F/CMVSS 207.
- Ford Motor Company lap and shoulder belts, retractors and attaching hardware should not be altered or modified in any way. The re-installation of these components should follow the instructions and specifications in the appropriate Ford Shop Manual.
- Lap and shoulder belt assemblies should be compatible with the seat systems and anchorages so that lap belts will be properly positioned about the occupant's pelvis to provide proper adjustment and fit. The buckle and buckle release must be properly located with respect to the occupant and must comply with the requirements of F/CMVSS 208.
- Upfitter processes should be reviewed to determine potential for contaminants to enter the seat belt retractors, buckle ends, or electrical connectors.

Temporary protective covers or other means (tape, plastic etc.) should be used to minimize potential for entry of contaminants.

- If any of the B-Pillar trim panels or cutaway retractor covers are removed to perform upfitter modifications, the upfitter must cover the retractor with (clean cover plate, tape, plastic etc.) to ensure contaminants do not enter the retractor housing.
- If drilling or cutting is done anywhere inside the vehicle, especially near the restraint system (even if not removed), due care must be used to cover/protect the restraint system (including the seatbelt webbing) to avoid damage or entry of contaminants (including covering all exposed trim holes on the B-pillars with tape).
- When seat belt assemblies (retractor, D-Ring and webbing) are repositioned or removed from the vehicle they should be positioned or stored in a clean environment and covered, with the webbing flat as to not induce wrinkling or creasing.
- After upfit, no hard contact should exist between any added component (i.e. bulk head partition, racks, second unit bodies or components) and any D-Ring, trim panel covering a retractor, or seat belt webbing. Hard contact can potentially damage retractor sensor parts and/or cause binding of the retractor affecting ability of the webbing to extract/retract.
- Seat belt warning system activation/deactivation, where applicable, should be provided by the lap and shoulder belt assembly.
- If seat belt retractors (and/ or D-Rings) are removed during the upfit process, or if any drilling/cutting is done inside the unit. Upfitters are requested to pull out and cycle the webbing 8-10 times to insure proper function and verify that any added upfit components are not causing a system restriction.

Occupant Protection Zone and Overhead Console

For vehicles completed with an Unloaded Vehicle Weight (UVW) greater than 2495 kg [5500 lb.], Ford Motor Company strongly recommends following the practices in the compliance representations for F/CMVSS 208 regarding overhead console specifications that apply to vehicles with a GVWR of 3856 kg [8500 lb.] or less and completed units have an Unloaded Vehicle Weight of 2495 kg [5500 lb.] or less.

Air Bag Supplemental Restraints System (SRS)

Ford Motor Company urges careful consideration of the recommendations that follow.

Detailed system and service information can be found in the Ford Service Manual for the appropriate vehicle line and model year. Ford Motor Company urges the subsequent stage manufacturers to become familiar with this system prior to modifying vehicles that are so equipped.

Depowering the SRS system: If electrical work is performed near the steering column, instrument panel or air bag system, the air bag system must be depowered to avoid unwanted inflation. To do this, follow the procedure described in the Ford Service Manual.

WARNING: To avoid accidental deployment and possible personal injury, the backup power supply must be depleted before repairing or replacing any air bag supplemental restraint system (SRS) components. To deplete the backup power supply energy, disconnect the battery ground cable and wait one minute. Be sure to disconnect auxiliary batteries and power supplies (if equipped).

WARNING: Carry a live air bag module with the air bag and trim cover pointed away from your body. This will reduce the risk of injury in the event of an accidental deployment.

WARNING: Do not set a live air bag module down with the trim cover face down.

CAUTION: Do not remove the steering column, steering wheel, and air bag module as an assembly from the vehicle unless:

- The column is locked to prevent rotation, or
- The lower end of steering shaft is secured (e.g., by wire) in such a way that the steering wheel cannot be rotated.

After repowering an airbag, it is important to prove out the system to make sure it is functioning properly. See the appropriate Ford Service Manual for the correct prove out procedure.

WARNING: The seat belt buckle pre-tensioners, air bags, and electronic sensor module are barcoded with a unique serial number which is matched to the vehicle VIN. To maintain the occupant protection system performance, the completed vehicle must contain the same seat belt buckle pre-tensioner, air bags, and electronic sensor module that were installed by Ford Motor Company. Failure to do so could result in serious injury in the event of a collision.

## Center of Gravity Location

The location of the vehicle center of gravity is a very important characteristic for determining whether the completed vehicle meets various FMVSS regulations (105, 126, 135, 301 etc.), vehicle limitations (GAWRs etc.) and desired attribute targets (steering feel, vehicle stability, handling etc.).

The reference features used by Ford for all center of gravity measurements are as follows: the ground plane for vertical CG, center of the front wheels for horizontal CG, and geometric center line of the vehicle for transverse CG.

### Definitions

The following expressions are defined for use regarding vehicle Center of Gravity. See Figure 39 for graphical representation of many of these terms.

**$CG_h$** = Horizontal distance from the center of the front wheels to the center of gravity of the completed vehicle

**$CG_{hb}$** = Horizontal distance from the center of the front wheels to the center of gravity of the Second Unit Body (SUB) and permanently attached equipment

**$CG_{hc}$** = Horizontal distance from the center of the front wheels to the center of gravity of the chassis, including cab

**$CG_{hl}$** = Horizontal distance from the center of the front wheels to the center of gravity of the cargo. $CG_{hl}$ may be estimated as the distance from the front wheel to the horizontal midpoint of the cargo area

**$CG_{hp}$** = Horizontal distance from the center of the front wheels to the center of gravity of the passenger load (P)

**$CG_t$** = Transverse distance from the geometric center line of the vehicle to the center of gravity of the completed vehicle (not shown in figure)

**$CG_v$** = Vertical distance from the ground to the center of gravity of the completed vehicle

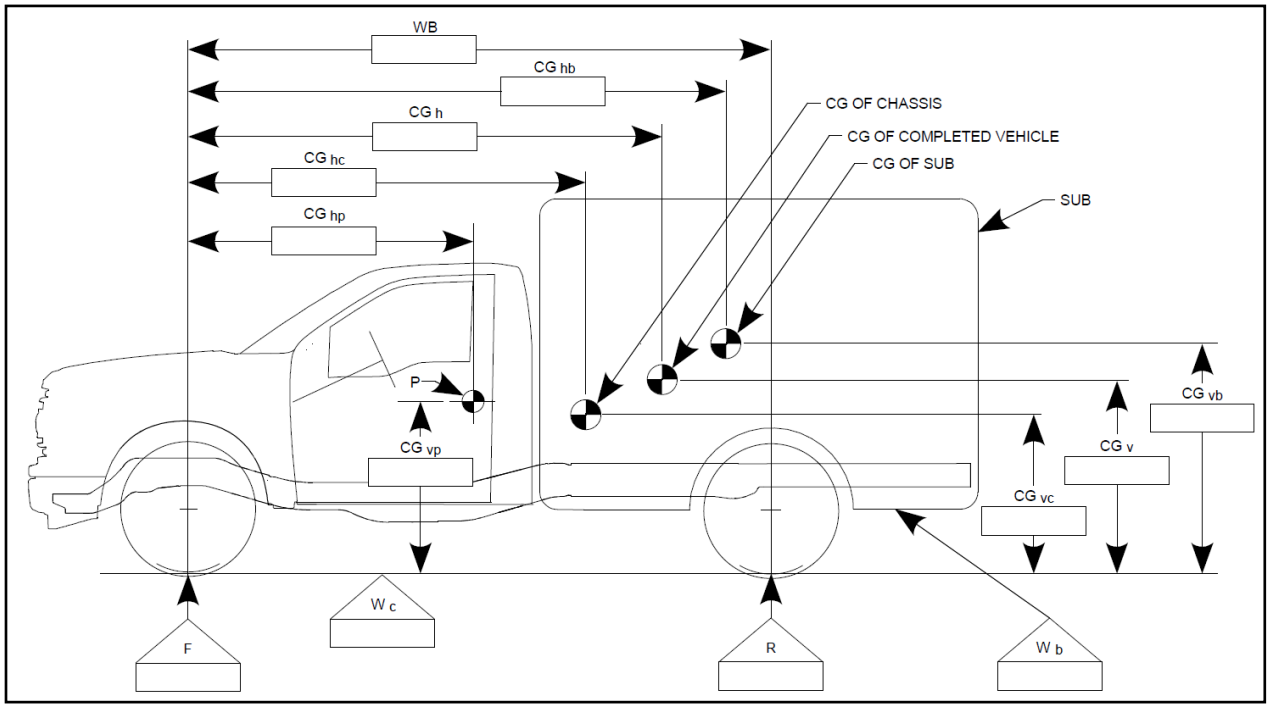



**Figure 39 – Center of Gravity Definitions**

**$CG_{vb}$** = Vertical distance from the ground to the center of gravity of the Second Unit Body (SUB) and permanently attached equipment

**$CG_{vc}$** = Vertical distance from the ground to the center of gravity of the chassis, including cab

**$CG_{vl}$** = Vertical distance from the ground to the center of gravity of the cargo

**$CG_{vp}$** = Vertical distance from the ground to the center of gravity of the passenger load (P)

**F =** Front axle weight. The sum of left front (LF) and right front (RF) corner weights

**LF** = Load on the left front wheel (corner weight)

**LR** = Load on the left rear wheel(s) (corner weight)

**P** = Passenger load. Defined in FMVSS 105 as 400 lb. for vehicles with GVWR 10,000 lb. and under, and 500 lb. for vehicles with GVWR over 10,000 lb.

**R** = Rear axle weight. The sum of left rear (LR) and right rear (RR) corner weights

**RF** = Load on the right front wheel (corner weight)

**RR** = Load on the right rear wheel(s) (corner weight)

**$T_f$** = Track width of front axle (not shown in figure)

**$T_r$** = Track width of rear axle (measured to center of wheel pair for DRW vehicles) (not shown in figure)

**WB** = Vehicle wheelbase length

**$W_b$** = Weight of the Second Unit Body (SUB) and permanently attached equipment

**$W_c$** = Weight of the chassis, including cab (fuel tanks full and including options and accessories)

**$W_l$** = Weight of cargo. Maximum cargo capacity: $W_{l(max)}$ = GVWR – ($W_c$ +$W_b$ + P)

**Determining Center of Gravity Location**

Reference information

Reference information that may be helpful for calculating center of gravity locations is available on the Ford Body Builder Advisory Service (BBAS) website https://fordbbas.com, under "Publications". The Body Builder Layout Books contain chassis base curb weights (front and rear), GAWRs, chassis $CG_v$, Passenger CG location, and dimensional information such as wheelbase and track width. Option weights are listed in the Ford eSourceBook, which can be found under "Vehicle Specifications". If you do not have access to this information online, please contact your Ford Dealer.

Aggregation of Components

The location of the center of gravity of an assembly can be calculated using a weighted average equation. Figure 40 is an example of a weighted average equation used to calculate the center of gravity of a completed vehicle from its four main components: Chassis, Passenger, SUB and Payload. This method can also be used to calculate the CG of a SUB from its components, or for any other assemblage of parts. This equation can be applied separately to any of the three vehicle directions (vertical, horizontal and transverse). Make sure the data units and measurement reference features are consistent throughout the equation (e.g. all lengths are in inches and measured from the ground, all weights are in pounds, etc.)

There are also various software tools that can be used to calculate the center of gravity location of a completed vehicle. For instance, the National Truck Equipment Association (NTEA) has a useful web-based tool that is available to its members. It can be accessed at:

www.ntea.com/weightcalculator

Note: Ford Motor Company is not responsible for the accuracy of results obtained with third party calculators.

$$CG = \frac{(CG_b * W_b) + (CG_c * W_c) + (CG_l * W_l) + (CG_p * P)}{W_b + W_c + W_l + P}$$

**Figure 40 – Weighted Average Equation Example**

$$CG_h = \frac{R * WB}{F + R}$$

**Figure 41 – $CG_h$ Calculations from Weight Data**

$$CG_t = \frac{LF * T_f + LR * T_r}{LF + LR + RF + RR}$$

**Figure 42 – $CG_t$ Calculations from Weight Data**

Using Weight Measurements

It is possible to determine the CG location for a vehicle in any state of completion (chassis as provided, up to a completed vehicle loaded to GVWR) by taking weight measurements, or in some cases, using provided weight information. This may be beneficial in many instances, for example, to confirm a calculated value (particularly if the value is close to a required limit), or where it is not possible or practical to calculate the CG location. The weight measurements required vary in complexity based on which vehicle direction (vertical, horizontal or transverse) is of interest.

For horizontal center of gravity ($CG_h$ or $CG_{hc}$), the front and rear axle weights are required. Figure 41 shows how to determine the vehicle $CG_h$ from the front and rear axle weights and wheelbase length. Front and rear axle weights can be calculated from the four corner weights if that information is available. This method is particularly helpful in determining horizontal CG of a Ford chassis ($CG_{hc}$) using the front and rear curb weights as provided in the BBLBs.

To determine transverse center of gravity ($CG_t$), the four corner weights, along with front and rear track widths (front and rear track widths are often different, especially for DRW vehicles) can be used in the equation in Figure 42.

The methods for determining vertical center of gravity are significantly more complex than for the other directions. For critical applications requiring the most accurate results, some test labs have specialized “Vehicle Inertia Measurement Facility” (VIMF) equipment that may be used. A more common method utilizing widely available equipment (scales and a vehicle lift) can be performed by a certified test facility, or at a minimum, by a properly trained and qualified technician. If interested in performing a $CG_v$ measurement, the test method can be found in the Transit Body and Equipment Mounting Manual (BEMM) in section 1.12.3 “Center of Gravity Height Test Procedure”. Navigate to the Ford Body Builders Advisory Service (BBAS) website https://fordbbas.com, go to the "Publications" tab and expand the “Body Builder Layout Book” section to find the Transit BEMM.

Loading Conditions

It is recommended to calculate or measure the CG location of a completed vehicle in at least two loading conditions:

- Unloaded Vehicle Weight (Chassis + SUB)
- GVWR (Chassis + SUB + Passengers + Payload required to bring vehicle to GVWR)

For Bus applications or vehicles with more than one payload location, it may be valuable to also calculate CG location(s) for one or more partial loading conditions (i.e. passengers and/or payload in different locations).

**Assessing Center of Gravity Location**

CG Location Example Calculation

To illustrate how to assess CG locations, the following example vehicle will be used:

Chassis: F550 Super Duty, Regular Cab, 19.5k GVWR, 145" Wheelbase (60" CA), 4x4, 6.7 Diesel, FGAWR = 5600 lb., RGAWR = 14706 lb.

SUB: 9ft Mechanics Body with Crane and Liftgate

Gathering the needed reference information from Ford Publications and upfitter websites, and using the equation in Figure 40, the following CG locations were calculated:

- Completed Vehicle at UVW (W = 11,294 lbs.)
  - $CG_v$ = 39.0 in
  - $CG_h$ = 84.3 in
- Completed Vehicle at GVWR (W = 19,500 lbs.)
  - $CG_v$ = 45.3 in
  - $CG_h$ = 107.8 in

Axle Loads and GAWRs

Every vehicle has Front and Rear GAWR limits that must be adhered to. The GAWRs inherently restrict the allowable $CG_h$ range depending on the vehicle weight, as shown in Figure 43 for the example vehicle (the Chassis, UVW and GVWR conditions are also plotted). The higher the vehicle weight, the more limited the range of allowable $CG_h$ location such that GAWRs are not exceeded.

For verification purposes, the calculated $CG_h$ values can be used to determine the Front and Rear Axle Weights for each loading condition, which can then be directly compared to the GAWRs. Figures 44 and 45 show the equations for Rear and Front Axle Weights, respectively. If the Front Axle weight exceeds the FGAWR value, the $CG_h$ must be moved rearward to transfer the excess weight to the rear axle, and vice versa.

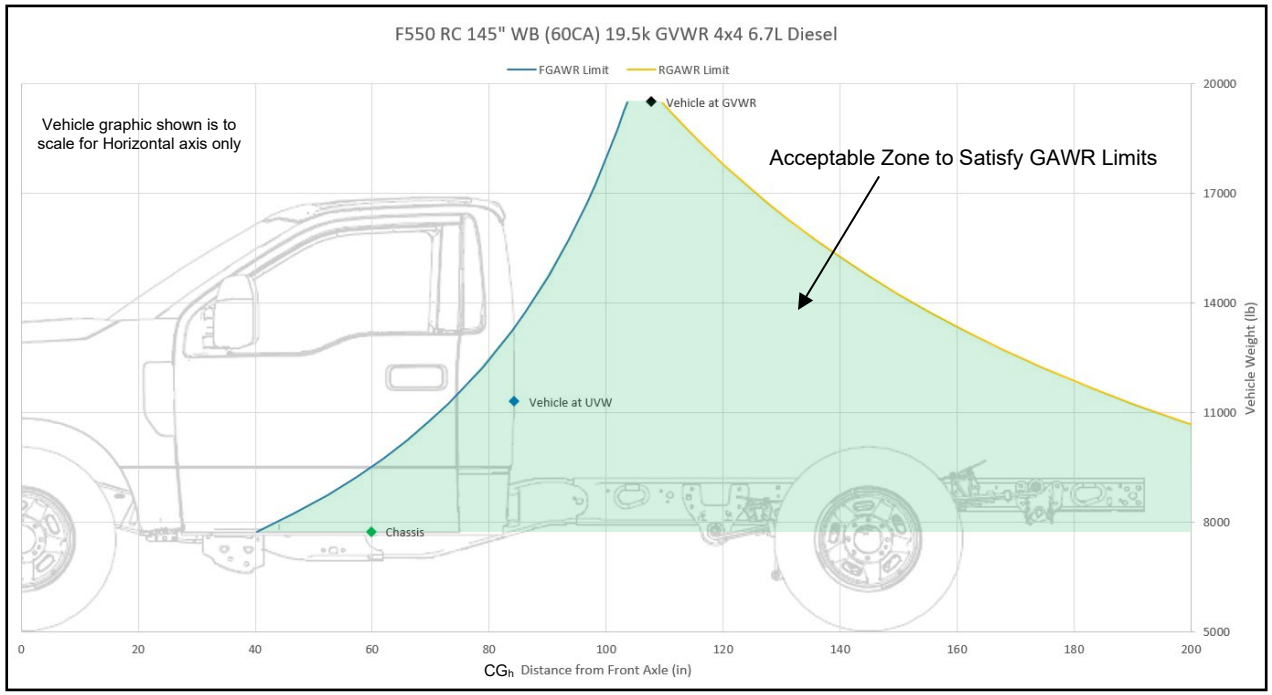



**Figure 43 – Relationship of GAWR Limits to $CG_h$ Location (Example)**

$$R = \frac{\mathrm{CG}_h * W}{\mathrm{WB}}$$

**Figure 44 – Rear Axle Weight Calculation using $CG_h$**

$$F = \frac{(1 - \mathrm{CG}_h) * W}{\mathrm{WB}} \quad or \quad F = W - R$$

**Figure 45 – Front Axle Weight Calculation using $CG_h$**

FMVSS Requirements

Some Statements of Conformity in the Ford IVMs have limits on the vertical center of gravity of the completed vehicle ($CG_v$). In many cases the calculated $CG_v$ values (such as in the example) can be compared directly to the limits provided in the IVMs.

On some vehicle lines, CG limits related to FMVSS 105 are presented in the IVMs as a pair of equations: Max and Min $CG_v$ values expressed as a function of the horizonal CG location ($CG_h$) and wheelbase of the vehicle. The calculated $CG_v$ value must be between the Max and Min $CG_v$ results from the equations for all loading conditions. The Max and Min $CG_v$ results are only to be considered for compliance to FMVSS 105, they are not targets or recommendations for the vehicle CG location in general.

Figure 46 shows a graphical representation of the Max and Min $CG_v$ equations, as well as the calculated CG locations for the example vehicle.

Interpretation of Max and Min $CG_v$ results from FMVSS 105 equations:

- If the calculated $CG_v$ is above the Max $CG_v$ result from the FMVSS 105 equation, the vehicle CG must be lowered or moved rearward. In some cases, the Max $CG_v$ result might be a negative value; meaning the $CG_h$ needs to move substantially rearward to bring the Max $CG_v$ up to a workable value. It is not

unusual for the Max $CG_v$ result to be a very high number; please remember this is a maximum value, not a target or recommendation.

- If the calculated $CG_v$ is below the Min $CG_v$ result from the FMVSS 105 equation, the vehicle CG must be moved forward (preferred) or could also be raised if necessary. It is not unusual for the Min $CG_v$ result to be a negative value.

If desired, the FMVSS 105 Max and Min $CG_v$ equations in the IVMs can be rearranged to solve for Max and Min $CG_h$ as a function of $CG_v$ and Wheelbase.

Ford Recommendations

Where applicable, IVMs for some vehicle lines provide a practical "recommended" $CG_v$ limit (typically as part of the FMVSS 105 Statement of Conformity), to help guide subsequent stage manufacturers toward a completed vehicle that will meet or exceed customer expectations.

It is a general best practice to keep the $CG_v$ of a given vehicle as low as practical.

It is the responsibility of the Final Stage Manufacturer to ensure the performance and safety of the completed vehicle.

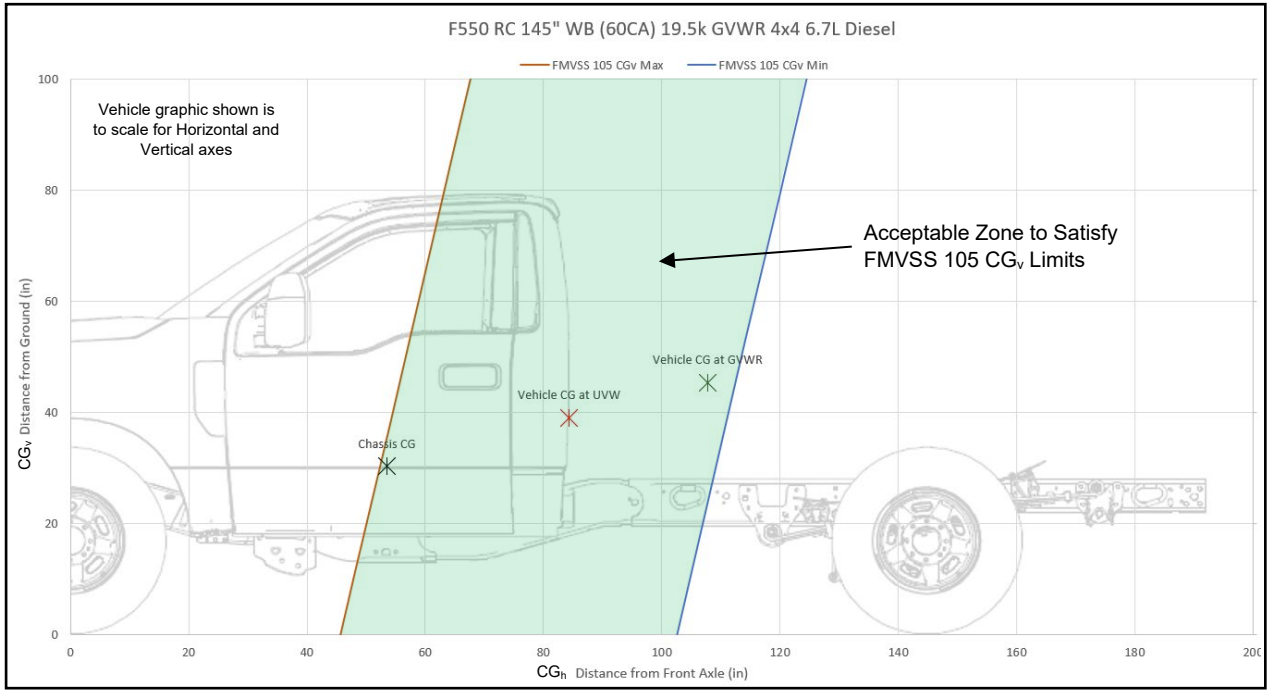



**Figure 46 – FMVSS 105 Max and Min $CG_v$ Equations (Example)**

## Change Control

Revision 2 (10-Feb-21) - modifications from 2021MY Revision 1 version:

- Clarified standards for fuel lines in “Fuel Lines, Hoses and Pumps” section (page 14)
- Added recommendations for aux fuel powered equipment in “Fuel System Access for Auxiliary Fuel Powered Equipment” section (page 14)
- Added comment regarding LH exhaust in “Exhaust” section (page 28)
- Added further clarification to “Assessing Center of Gravity Location” section (pages 41-42)
- Fixed hyperlink for SAE 2727 on page 24.

Revision 1 (15-Oct-20) - modifications from 2021MY Initial Release version:

- Added content on Loading Conditions and Assessing Center of Gravity Location in the “Center of Gravity Location” section (pages 40-42)

Initial Release (10-Jul-20) - modifications from 2020MY R2 version:

- Added suggestion to keep vehicle in Transport Mode during storage of new vehicle (page 8)
- Added cautionary information regarding coatings to Heat Management section (page 11)
- Added section on Transport Mode (page 15)
- Added section on Module Configuration / Calibration (page 15)
- Added cautionary note regarding connecting devices to the battery (page 16)
- Added additional information regarding PWM (page 18)
- Revised information on A/C hose and fittings and added statement regarding California GHG emissions to Climate Control section (page 24)
- Revised clearance recommendation between underbody coatings and exhaust (page 25)